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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 10, No. 9 MARCH, 1939 25c a copy

Field welding of superheater tube connections in a large steam generating unit

Ash Disposal at the Schuylkill Station

pH and pOH Explained

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COMBUSTION

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VOLUME TEN NUMBER NINE

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FOR MARCH 1939

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DEPARTMENTS

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EDITORIAL

Bituminous Coal Prices

Although coal furnishes at least sixty per cent of the energy produced by stationary plants in the United States and promises to continue as our major source of supply, the bituminous coal industry has been in a bad way for many years. This condition has been intensified by the inroads of competitive fuels, such as oil and natural gas, and by the steady improvement in economy of power generation. The Government's program of hydro development may be regarded as an additional threat to the coal industry. Notwithstanding the increase in population there has been a marked decline from the peak of coal production in 1918.

The vast number of bituminous coal producers, the wide variation in the product and diverse market conditions have defied any widespread attempt at self-regulation. From time to time various boards were set up to study the situation and make recommendations, but little came of their efforts because of the almost insurmountable obstacles involved. It was not surprising, therefore, that many operators, despite an aversion to governmental regulation, saw hope in the passage of the National Bituminous Coal Act of 1937.

The brief period during which the first minimum price fixing schedules were in effect was perhaps too short to provide any measure of their effect on the industry or on the consumers, for stocks had been built up in anticipation of the new prices, certain sizes proved a temporary drug on the market, and some attempts at chiseling as to grading were reported. Withdrawal of the schedules, after being in force about two months, because of certain court decisions, cut short the story. This was early in 1938. Since then the Commission has been laboring assiduously toward the establishment of new schedules and in this effort has had the general cooperation of producers. This has been a tremendous task and it is probable that several months will elapse before the new prices are an nounced.

As the time for such announcement approaches there is an apparent division of opinion among coal producers as to the ultimate benefits to the industry. To cite one such adverse opinion, J. D. A. Morrow, President of the Pittsburgh Coal Company, speaking recently before the A.I.M.E., observed that taxes and assessments levied under the Act had amounted to between 6 and 8 million dollars, on an already overtaxed industry. This is aside from the greatly increased expense of additional clerical help necessitated in compiling and submitting statistical reports, and the time and expenses of hundreds of employees of coal companies and associations engaged in administration of the price-fixing provisions of the Act. Moreover, Mr. Morrow estimated that the demoralization of coal prices generally attributed to the Act had caused a loss in revenue to the industry of approximately 50 million dollars, in addition to a further loss of 15 to 20 million in the brief period during which the prices were in effect. "The Merits and Demerits of Federal Regulation in the Coal Industry" is a topic scheduled as one of the high points for discussion at the forthcoming convention of the American Mining Congress in Cincinnati, April 24 to 28.

Speculation as to the effect of the new minimum prices is futile at this time. That they may cause some temporary dislocation of the coal markets seems likely; but it is also reasonably certain that modification of the schedules or changes in the Act itself, if made at all, will be deferred until after a sufficient period has elapsed to permit both producers and consumers to adjust themselves to the new setup. Meanwhile, it is significant that many of the newer boiler installations have provision for firing competitive fuels should market conditions warrant such action.

There are many who entertain the long-range view that the salvation of the coal industry lies more in constructive research than in arbitrary price fixing.

Years in College

It has often been contended that a liberal and cultural education, in terms of an academic course, is an essential prerequisite to a technical training, if the engineering profession is to achieve and hold its deserved place in our present complex social structure. That such a foundation is desirable, few will deny; but there is room for a division of opinion as to whether it should be mandatory in our educational system, especially when one considers that the extra years in college may bar many promising young men for financial reasons.

Most engineering colleges have liberalized their curricula to include certain cultural subjects to supplement basic engineering courses, leaving technical specialization to post-graduate years. Furthermore, much more of a civic, social and general scientific nature is now being taught in the high schools than was the case twenty years ago, and innumerable opportunities are afforded for adult education. In fact, education never ceases for those desirous of taking advantage of such opportunities.

What management is seeking today is young men with a reasonable amount of technical and cultural training, a sense of economic values, and who have the ability to grow and assume positions of responsibility and administrative work in the organizations with which they are connected. Important in this respect is the handling of problems in human relations, but such ability cannot be gained in the classroom; it is to a large extent inherent in the individual and must be further cultivated by experience and maturity of judgment. Young men who successfully meet these requirements will be the industrial leaders of tomorrow.

As for assuming a role in civic affairs, a field in which engineers are admittedly scarce, it would seem that much depends upon the individual regardless of his educational training. Whether a greater amount of cultural training would result in more engineers taking part in public affairs remains questionable.

ASH DISPOSAL AT THE SC

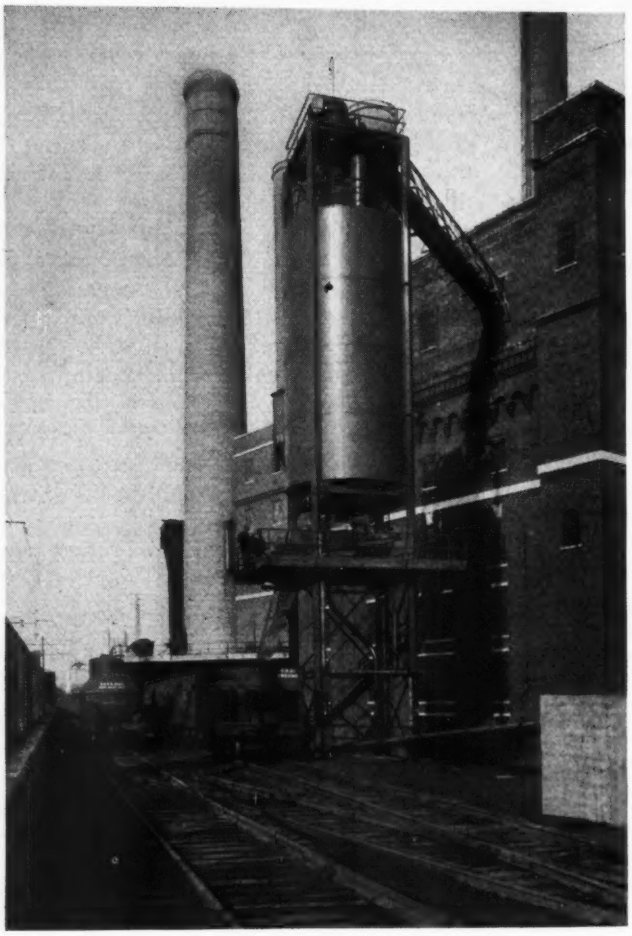

Fig. 1—Fly-ash receiver, bridge carrying transport line, and unloader to cars

Each of the two high-pressure boilers at this station of the Philadelphia Electric Company burns 27 tons of pulverized coal per hour when operating at rated capacity. About half of the ash from this coal is discharged in molten state from the continuous slagging bottoms and the other half, or fly ash, is handled by electrostatic precipitators. The molten slag is disintegrated by water and pumped to an outdoor pit, containing dewatering elements, from which it is removed by a grab bucket. The fly ash is collected in hoppers and transported by vacuum conveyor to an outdoor tank. Here some water is introduced to facilitate loading into railroad cars.

WHEN additional capacity was considered for the Schuylkill Station[1] at Philadelphia, the question of slag and fly-ash disposal from the new boilers presented a problem. This plant is in a concentrated residential and industrial area; therefore, land that might be utilized for ash disposal purposes is not available.

Two 600,000-lb per hr, 1350-lb pressure, 910-F pulverized fuel fired boilers of the continuous slag-removal type, each equipped with electrostatic fly-ash precipitators, have been in operation since October 1938. They serve a 50,000-kw superposed turbine-generator with steam at 1250-lb gage and 900 F temperature. At 600,000 lb per hr evaporation, each boiler burns approximately 27 tons of coal. About one-half of the ash, by weight, flows from the furnace bottom in the form of molten slag. The other half is carried with the gases through the boiler in the form of dry fly ash. In order to dispose of the slag and fly ash, two separate systems, capable of being operated individually or in combination, are installed. Slag is normally handled by a so-called wet system where water is used as a conveying medium. Fly ash is ordinarily collected in a dry-vacuum system. The combined equipment is shown schematically in Fig. 2.

The Slag Handling System

Under the slag-tap opening of each boiler there is a water-filled receiving hopper having a capacity of approximately 500 cu ft. As the slag discharges continuously from the opening in the furnace floor it is disintegrated by this water. Periodically, the disintegrated slag is removed. These hoppers are constructed principally of cast-iron plate. The sides and roof are lined with refractory material and the hoppers are provided with access doors for inspection. Concrete, lined with firebrick, forms the chamber floor. The design thus eliminates any internally exposed metal.

The slag discharges from each hopper through a hand-operated decanting door, and a manually-operated oscillating nozzle mines the slag, permitting it to flow into a transport trench about 18 in. wide. This trench, formed with concrete, is lined with half-round alloy steel liners held in place by means of lugs gripping the side walls. Throughout the length of the trench, transport nozzles are located at intervals to assist in propelling the slag. Where the trenches from the two boiler hoppers meet, alloy steel wearing plates are located. Plates covering the assembly permit access for observation and inspection.

From the sluicing trench the slag discharges into an indoor transfer sump which is protected by wearing plates and contains additional agitator nozzles and a float-controlled water make-up valve. Two horizontal slag pumps, located adjacent to the sump, pump a mixture of slag and water to the outdoor pit. The ash

[1] See "Superposition at Schuylkill Station," by E. L. Hopping, COMBUSTION, June 1937.

SCHUYLKILL STATION

By N. J. WALKER
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pumps, each rated at 1750 gpm are V-belt driven by 60-hp motors. To insure long life while handling the highly abrasive slag, special sealing features and rubber liners are inserted. Proper sealing protection of the internal parts of the pump make it possible to operate at practically a constant point on the efficiency curve throughout the life of the moving parts. Slag is discharged from the ash pumps through the two 8-in. lines, each approximately 375 ft long, leading to an outdoor slag pit. The lines are cast from a hard alloy designed particularly to resist attack by abrasion. The outdoor pit has approximately 7600 cu ft capacity and contains dewatering elements, permitting the water to be decanted so that the slag may be collected by a grab bucket. Dewatering pipes around the inside of the pit are protected by removable steel rails. Adjacent to the slag pit is an 8000-cu ft clear well into which the decanted water flows as shown in Fig. 2. Fig. 3 is a photograph showing the two 8-in. slag lines which discharge into the outdoor pit. Adjacent to the slag pit is the clear well just mentioned. The equipment installed is capable of handling slag at a rate varying between one-half ton and one ton per minute.

Two recirculating water pumps, shown in Fig. 2, take their suction from the outdoor clear well. They supply

Fig. 3—Slag pit with clear well beyond

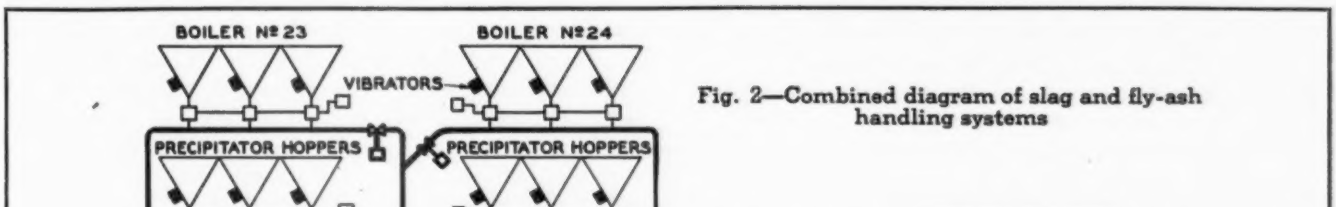

Fig. 2—Combined diagram of slag and fly-ash handling systems

transport water for the slag in both the sluice-ways and the ash-pump discharge lines. They also feed the hydraulic jet ejectors which create a vacuum for removal of dry fly ash. The recirculating pumps are, in general, similar in design to the slag pumps but are rated at 1700 gpm each. They develop 350 ft total head which is necessary to the operation of the vacuum producing ejectors for the fly-ash system described below. Individual 300-hp direct-connected motors drive these pumps and when only slag is handled, one ash and one recirculating pump are sufficient. For simultaneous operation of slag and fly-ash systems, two ash and two recirculating pumps are required. The possibility of increased capacity in the future prompted provision of space for a third ash pump and a third recirculating pump.

The Fly-Ash Handling System

A complete system for handling fly ash, identified as a dry system, is also provided as shown in Fig. 2. This ash is collected in hoppers under the electrostatic precipitators and under the economizers on each boiler. A pipe line conveyor under vacuum transports the material to an outdoor dry fly-ash tank. A rotary dustless unloader into which the proper quantity of water is introduced, provides for the discharge of slightly moistened fly ash into railroad cars on a siding below the unloader. However, should emergency conditions of any nature warrant the procedure, fly ash from the hoppers may be bypassed directly to the indoor slag transfer sump and be transported wet into the outdoor slag pit. The two hydraulic-jet ejectors, located above the slag transfer sump and supplied by either of the recirculating pumps described under the slag system, create the vacuum in the fly-ash transport lines. As shown in Fig. 2, there are six collecting hoppers under the precipitators for each boiler. Likewise there are four hoppers under each economizer. Rotary vane feeders, motor operated in groups, unload the fly ash from these hoppers into the transport lines. In addition, the precipitator hoppers are equipped with motor-operated internal vibrating plates which facilitate flow of the fly ash. Approximately 800 ft of 5- and 6-in. I.D. conveyor pipe provide for delivery of dry fly ash to the outdoor storage tank.

The line is sectionalized by means of thrustor-operated plug valves which are remotely controlled and permit the emptying of groups of hoppers at one time. In Fig. 2 it will be seen that there are five thrustor-operated valves. All other valves are operated manually. The thrustor is essentially a motor-driven oil-immersed centrifugal pump. The pressure of the oil on a piston operates the valve so that it opens when the motor is energized and closes by a spring when the motor is de-energized. A selector at the control board opens the thrustor valves in the transport lines before the rotary vane feeders deliver fly ash into the line. When the hoppers are emptied, the operating feeder motor and thrustor valve motors in the lines are manually tripped. The thrustor valves close after the vane feeders have been stopped. Thus the transport line is cleared of fly ash.

Fly ash is carried into a receiver and separator located above the outdoor storage tank. A timer and thrustor-operated vacuum-breaker regulate the periodic automatic operation of a gravity swing gate which discharges the fly ash into the 6500- cu ft steel storage tank. Thrustor valves close and feeders stop automatically before the vacuum is broken to prevent deposits in the transport lines. A bag filter cleans the air to be returned to the hydraulic jet ejector units. To prevent escape of dust when material is dropped from the receiver and bag filter, the tank is provided with a filtering vent. Should fly ash accumulate on the bag filter, the vacuum differential is increased, an alarm is sounded, and the make- and break-circuit for the vacuum is automatically opened. Provision is also made for a signal alarm in case of high dust level in the tank.

A motor-operated vibrator assists the flow of fly ash into the 20-ton per hr rotary dustless unloader mentioned above, which is driven by a geared 5-hp motor. A swing chute, provided with a vibrator, delivers the moist mixture into cars; see Fig. 1, which is a photograph showing in the background the bridge carrying the fly-ash transport line into the receiver, tank, dustless unloader, etc.

The fly-ash system has a capacity of 8 tons per hour when using 1500 gpm of 140-lb water at the ejector units. When the fly ash is discharged directly to the indoor slag transfer pump, used only under emergency conditions for this purpose, the capacity is increased to 12 tons per hour, since the friction loss through the conveyor lines, fly-ash tank and return air line is eliminated.

The storage tank was so located and the general arrangement designed so that bagging equipment could be installed at a later date if a suitable market for fly ash should develop.

Central Control Board

An ash-control board for both of these systems, is located between the two boilers at the basement floor level. From this location, the operator has control of practically all of the indoor operations necessary in handling slag or fly ash. The vacuum gage on this board is connected into the air line on the suction side of the water ejectors and indicates to the operator when the fly-ash conveying operation from any group of hoppers has been completed. Starting and stopping of the various pumps, thrustor valves, feeders, etc., is also controlled from this board. Elimination of the necessity for stationing an operator at the hoppers under the precipitators and economizers was intended by this arrangement.

Operation

Following incidental changes and improvements usually required in initial operation, both systems have performed satisfactorily, as intended, with two remaining exceptions:

The presence of unexpected foreign material of various types in the economizer hoppers caused the rotary vane feeders to jam on a number of occasions, thus preventing operation of these feeders. A proposed method for solution of this problem is now being discussed with the manufacturers.

The rotary dustless unloader is operated at the platform directly beneath the fly-ash storage tank as shown in Fig. 1. The equipment is designed for outdoor service and no enclosure was provided for the unloader. However, some inconvenience has been experienced due to freezing, in extremely cold weather, of the residue in the unloader. Possible changes or additions to overcome this difficulty are being investigated.

Burning Oil-Refinery Fuels*

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The paper describes the various types of waste by-product fuels which are produced in an oil refinery and the burning of them in boiler furnaces. Composition and characteristics of these by-products are given together with the methods of handling and utilization. Burner design and the use of steam for atomization are considered and attention is called to the fact that combination burners have been developed to burn simultaneously five different fuels in liquid, gaseous and solid form.

OIL REFINING requires the utilization of relatively large volumes of fuels, among which are nonmerchantable by-product fuels, as well as high-grade merchantable fuels. In the following discussion, oil-refinery fuels will be classified as follows: (1) gas, coke and fuel oils, (2) sludges, (3) tars and (4) tank cleanings.

In this classification, the first group can be considered as high-grade, merchantable fuels, which serve as the basis for the evaluation of all other refinery fuels. This group of fuels is burned only after all by-product or nonmerchantable fuels are disposed of. In refineries where coke production is in large volumes, the greater percentage of this coke is a merchantable fuel, demanding a premium, particularly because of its adaptability to metallurgical and other uses requiring a relatively pure carbon. The amount of coke which cannot be considered merchantable, and which may be classed as a waste fuel for burning within the refinery, is small in volume, representing at most a negligible percentage of the total fuel burned. The remaining fuels listed can be considered as by-product or waste fuels, and the rest of the paper will deal mostly with these fuels.

Sludges are by-product materials from a purification process which uses sulphuric acid to remove tarry or gummy constituents from oil. Compared to fuel oil, some sludges are slow-burning and require high ignition temperatures to produce a reasonable heat release. They vary extremely in characteristics, depending upon the initial crude stock, method of treating and requirements of the finished product. Some sludges are readily blended with various tars to form a smooth-working fuel. Some have a heating value as high as 17,500 Btu per lb while in others it is as low as 9000 Btu on the "as-fired" basis. This variation is largely due to varying moisture content.

Due to the higher percentage of sulphuric oxide and water vapors in the products from the combustion of sludges, superheater supports, gas bypass dampers and economizer tubes deteriorate rapidly unless the exit-gas temperature is kept above the dew-point. Exit-gas temperature is not always a true indication of metal temperatures, particularly in the economizer section of the boiler where the actual shell temperature of the tube is considerably lower than the average exit-gas temperature. As is the case when using high-sulphur coals, problems still exist in connection with economizers and preheaters where high efficiencies are desired when sludges are burned.

Tar is not exactly defined in refinery terminology, and is a type of sludge from acid refining operations, or may consist of distillation residues. Its combustion characteristics are quite similar to those of sludges.

Nonmerchantable coke is usually a hard nonfriable substance containing a small quantity of volatile matter and varying percentages of sulphur and ash. If the small nonmerchantable portion of this coke is to be burned as pulverized fuel, it must be ground to a high degree of fineness. If petroleum coke is not finely pulverized the small particles pass out of the furnace partly burned, and may be deposited in the soot hopper or ducts.

Small amounts of light oils or tars of light gravity, which are a by-product of some treating operations, average about 19,000 Btu per lb, and may be successfully burned in a separate burner system. Great care, however, must be exercised in handling these fuels, as they usually have a low flash point and high volatility.

Tank Cleanings Require Special Handling

Tank cleanings, or "bottoms," consist of a considerable portion of oil of varying gravity and volatility, of dirt, water, salts, asphaltic and waxy semi-solid materials and often of iron scale. The heat value of this material will vary greatly, depending upon the proportion of its various constituents. Tank cleanings may be disposed of in liquid form through a grinding operation, or may be cooked up with fluxing oil, by means of which treatment, water, salts and noncombustible solids are settled out and rejected.

The grades and amounts of these various by-product fuels depend upon the crude run and the type of processing, but are seldom available in sufficient quantities to meet the entire fuel requirements of the refinery. The changing character of the sludge which constitutes about 90 per cent of the liquid residuals burned, is indicated in Table 1 which shows two typical laboratory determinations.

TABLE 1—SHOWING VARYING CHARACTER OF SLUDGE

Gravity	16.1 API	12.3 Bé heavy
Specific gravity	0.9587	1.092
Weight, lb per gal	7.984	9.105
Sulphur, per cent	4.03	7.43
Heat content, Btu per lb	17,219	13,555

* From a paper presented at the Spring Meeting of the A.S.M.E., New Orleans, La., February 23–25, 1939.

While these analyses are given as typical, the predominating characteristic of the sludges is extreme variability.

Sludges may be classed in two groups; those from treating gasoline and kerosene, and those from treating heating oils and other heavy petroleum products. The latter are distinguished by their thick viscous consistency, but they are not as corrosive as the lighter sludges.

Paraffine Sludge

This sludge is a by-product from paraffine-wax treating operations. In many cases this sludge causes considerable difficulty, as it becomes entirely solidified at atmospheric temperature. A large eastern refinery, however, has developed equipment for burning it that has proved satisfactory. The sludge is kept in agitation by steam jets and fluxed with a heavy viscous oil at the treating plant. It is then pumped to the boiler house into lead-lined storage tanks, which are equipped with closed brass heating coils located about six feet above the bottom of the tank. Agitation is effected by means of a mechanical mixer located below the heating coil. The storage tank is also provided with a ring of steam jets in the bottom that serves the dual purpose of heating and agitating the sludge. This sludge is burned in a separate fuel system similar to that employed for fuel oil. Burners using steam for atomizing are employed successfully and the sludge is supplied to the burners at a temperature of from 200 to 220 F.

Waste Fuel Ground Up as "Colloidal" Fuel

Additional waste fuels consist of all the wastes that have any combustible characteristics. These residues consist of gummy coke, heavy tank bottoms, muck, asphaltic residues, and slop, i.e., plastic solids or semi-solid materials which are neither truly solids nor liquids, and cannot be pumped. Collected and dumped into a pit, they may be ground or processed by the wet-pan type of grinder. The product of this operation is a frothy liquid containing appreciable quantities of carbon particles up to $^1/_8$ in. or more in diameter. The quantities of these wastes are generally not sufficient at any one time to warrant continuous operation of separate burning equipment for their individual disposal. In many cases the cost of disposing of these wastes in any other manner is prohibitive.

Sludge Handling and Storage

The storage and handling of sludges and tars present no difficult problem when the usually accepted standards are maintained. Lead-lined tanks are used for receiving and storing the sludge. These usually are equipped with steam jets to provide constant agitation and proper consistency for pumping and burning, although many sludges are burned without additional heating or agitation. Wth all fuel-burning equipment, constant flow through tihe supply and return lines must be maintained in order to prevent stoppage of the system. It is frequently necessary, when shutting down a sludge-burning system, to have the line thoroughly blown out with steam to purge it completely of coke particles which tend to solidify and plug the line. Otherwise the line may have to be dismantled for cleaning. Receiving and storage tanks may be equipped with an acid-fume arrester, if necessary, to collect and dissolve any objectionable acid fumes that may originate through blowing or agitating operations.

Pipes and cocks used for handling the acid sludges are made of brass. This material contains about 85 per cent copper and 15 per cent zinc and usually can be considered as satisfactory.

The pumping quality of sludge is good in most cases and offers no particularly difficult problem in winter or summer. Reciprocating pumps of the type in general use for handling liquid fuels are utilized and in most cases are satisfactory. Pump-valve construction is of various types, being spring-actuated or of the plain rectangular-block type, depending considerably upon the extent of repairs necessary for maintenance. Pistons, piston rods and lines usually are of acid-resisting bronze of sufficient hardness to avoid excessive wear.

Fuel Burning Equipment

When faced with burning a variety of liquids, semi-liquids and solid by-product fuels, a novel combustion problem presents itself. The furnace design usually follows the accepted standards for high rates of combustion and steam generation and serves as an efficient plant for the disposal of by-product fuels as well.

It is generally desirable to have a combined-type burner, capable of burning a combination of gaseous, liquid or pulverized solid fuels without changing burner parts, or which permits all of these fuels to be burned simultaneously.

One refinery has one of its three large boilers, each of which is designed to produce a maximum of 225,000 lb of steam per hr at 650 lb per sq in. and 740 F, equipped to burn five separate fuels simultaneously, i.e., fuel oil, refinery gas, petroleum coke, acid sludge and colloidal fuel. The other two boilers are equipped to burn refinery gas, bunker fuel oil and sludge at the same time. Another boiler plant, consisting of four boilers, each with a capacity of 50,000 lb of steam per hr at 380 lb per sq in. and 650 F, has twelve burners to each boiler. Seven of the burners may burn either fuel oil or sludge; the remaining five are for refinery gas. This boiler house generally is referred to as the waste-fuel disposal plant and burns waste fuels entirely when the supply is sufficient to carry the full load. Fuel oil is used only to keep settings warm when sludge is not available.

All boilers on which sludge is used as fuel are equipped with water walls and economizers. Induced and forced draft are used at the large plant, while induced draft is used at the smaller plant.

A full complement of indicating, recording and integrating meters is advisable on high-pressure steam-generating units burning refinery by-products and sludges as fuels, as efficient burning of such fuels reduces the amount of commercial fuels required.

Combustion controls are usually operated manually due to the constantly changing heat content and varying amounts of the fuels.

Indicators are essential to detect instantly the presence of smoke. Smoke indicators used in conjunction with duplex gas recorders have been invaluable in securing maximum efficiency from the various fuels.

Due to the various fuels burned, a multiplicity of piping and valves introduces rather complex operating fea-

tures. Steam is employed in most cases to purge supply and return lines, headers and burner connections, when it is necessary to change burners.

Burner Design

In firing various sludges, the most important factor is good atomization to reduce the sludge to a fine mist for its complete combustion. Of the various approved methods of atomization, steam has generally been used for the liquid sludges, which often are of high specific gravity and contain a considerable amount of solid matter, carbonaceous or otherwise, in noncolloidal suspension. Due to these conditions, there has been much development in designing burners that would be successful in burning the various kinds and grades of refinery liquid sludges without deteriorating too rapidly.

Factors that usually determine the selection of a burner are: (1) simplicity of design; (2) low cost of installation; (3) thorough atomization of cold sludges; (4) low pump pressure; (5) flexibility and efficiencies on swinging loads; (6) capability of bringing a cold boiler on the line at short notice; (7) ability to burn extremely heavy oils and sludges; and (8) resistance to erosion and corrosion.

A burner in one refinery has been designed to burn successfully the different grades of sludge at a pressure of 50 lb per sq in. and a temperature of 110 F. Effort was made at first to heat the sludge to lower its viscosity, but considerable plugging of the lines and burners resulted and it was finally decided to burn the sludges cold. The burner in design conforms to the outside-mixing type. The sludge and steam are admitted under pressure through separate valves and pipe arrangements into the burner tip before atomization takes place. The diffusing nozzle for atomization is located in the tip of the burner. This nozzle has a number of steam ports placed tangentially at the end of the nozzle in relation to the sludge stream and depends upon atomization of the burner tip. This arrangement avoids excessive burner wear. The burner tips are made of alloy metal that will withstand the strong erosive action as well as the corrosive attack of the by-product fuels. The flame is a turbulent rotating cone that does not touch the rear wall tubes.

Some important advantages of this type of burner are as follows:

1 Pulsation in the furnace is avoided by allowing sufficient mixture of air and sludge vapors for combustion.

2 There is no objectionable smoke to foul the boiler tubes with a carbon deposit and cause a serious loss of capacity and efficiency.

3 The admission of excess air to the furnace is avoided.

4 The required burning conditions, consisting of good atomization and burning in suspension, are obtained.

5 Low sludge temperatures and pressures are sufficient.

6 The plugging of burners, due to large sludge particles reaching the burner tips, is avoided.

Regardless of the type of burner employed, satisfactory results cannot be obtained unless the furnace of the boiler is suited for the burning of by-product fuels. The design of the furnace must approach that suitable for good fuel oil by allowing sufficient furnace volume for maximum boiler requirements. The gas must be kept highly heated and afforded time and space in which to burn completely before reaching boiler heating surfaces.

The success of atomization with steam in many cases has been remarkable in that it has eliminated many of the objectionable features encountered in preparation and handling the heavy by-product fuels before they could be burned. The largest percentage of these by-product fuels is burned cold as it is received at the sludge storage tanks and is not fluxed with fuel oil to lower its viscosity.

Burning sludges cold has many advantages. It is difficult to obtain a metal with sufficient strength, corrosion resistance and thermal transfer efficiency to heat the sludge in a closed heater. Agitating and heating by means of steam jets is necessarily accompanied by excessive steam costs and increase of moisture content in the sludge. Agitating in some cases causes the coke, held in a semi-colloidal suspension in the sludge, to drop out in the tank, or in the lines and burners, thereby clogging them.

Operating Results

In the refinery operation previously mentioned, the coke-pulverizing equipment is of standard make as applied to pulverizing coal. It has not been in service long enough to provide any definite data on wear or maintenance costs. The small portion of nonmerchantable coke, as it comes to the boiler house, has a high carbon content with a varying ash content as shown in Table 2.

TABLE 2—ANALYSES OF COKE

	Sample No. 1	Sample No. 2	
Oil (separately determined)	7.4	8.3	
Sulphur (separately determined)	3.24	2.4	
Volatile matter	12.61	14.12	Per cent by weight
Carbon	78.2	80.27	
Moisture	0.77	1.21	
Ash	8.42	4.4	
Hardgrove scale	38	56	
Btu per lb	14,500	14,972	

The presence of part of the volatile matter may be explained by the surface oil which accumulates after the coke bed is formed. In grinding, this oil naturally spreads over the fine particles of pulverized material and must be consumed by surface burning when injected into the furnace. While the surface burning is in process, the coke particle is traveling to cooler parts of the setting where combustion is slowed up.

Due to the mineral-ash content present in petroleum oils and removed by means of the acid treatment, which is finally deposited in the sludge, considerable slagging of an objectionable nature is often experienced on the boiler settings while burning these sludges. This slag, in many cases, adheres to the firebox row of screen tubes, the burner-panel water tubes, and particularly to the flat bottoms of the furnaces, when they are employed as sludge-burning units, thus lowering the boiler rating and efficiency to a considerable degree.

It is practically impossible to secure a reliable heat-unit balance or true boiler efficiency on sludges that are burned as waste fuel. Due to slagging and fouling of the settings, maintenance and repair costs should be apportioned to the various grades of by-product fuels burned. This is accomplished best by establishing a reasonable operating efficiency for the basic fuel, and debiting or crediting any loss or gain against the waste fuels or the department that produces the by-product material.

Recent Practice in Power Piping

By SABIN CROCKER
The Detroit Edison Company

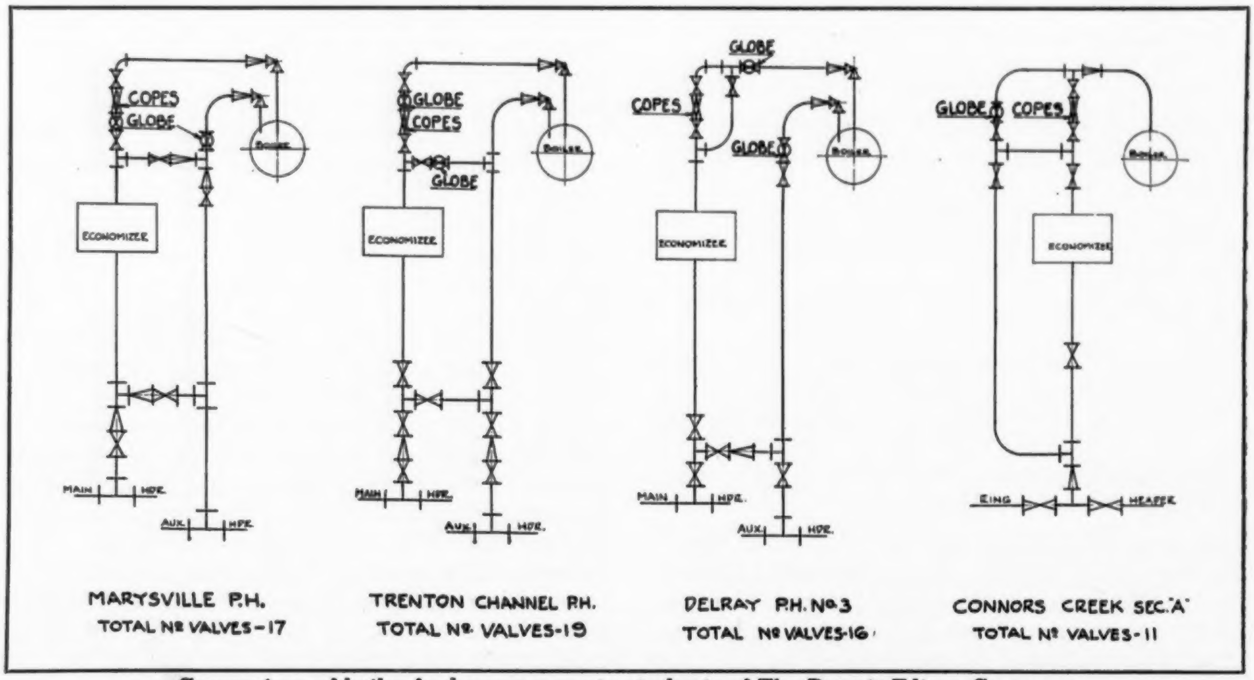
The author reviews the progress in power piping during the last fifteen years which has led to a more reliable but less expensive product. Particular attention is given to piping for high-pressure and high-temperature service and the influence of present-day methods of inspection is discussed. Some typical installations are illustrated.

IN THE modern power plant, piping of all descriptions usually costs somewhere between five and ten per cent of the entire plant investment, including equipment, buildings and land. While on this basis the piping may seem a rather insignificant part of the whole plant, nevertheless the high-pressure, high-temperature lines involve a variety of engineering problems whose solution probably has commanded as much attention as any other phase of steam engineering. Among a few of the more important items are carrying capacity and frictional loss, allowable hoop or girth stresses under elastic and under plastic conditions, expansion and flexibility, improved materials, design of flanged joints and the development of safe welded joints embodying numerous novel improvements over former construction. It is interesting that, despite the trend to higher pressures and temperatures, the cost of power piping has substantially decreased, due chiefly to improved methods of fabrication which in themselves are less expensive but more reliable. This, in turn, has justified further economy through a reduction in duplicate pipe services on the score of improved reliability. I have in mind recent ideas on the simplification of ring headers, the reduction of double valving and the partial elimination of dual lines, such as main and auxiliary feed systems.

Within the past fifteen years steam pressures and temperatures have risen by leaps and bounds, while oil refinery and other process work has been revolutionized, thus creating an ever increasing demand for corresponding advances in piping practice. This has, indeed, been the golden era for piping during which the product has risen from an obscure article hidden on the back shelves of steamfitters' shops to a much publicized commodity dignified through numerous American standards for dimensions and material specifications, and with national codes covering its application and use.

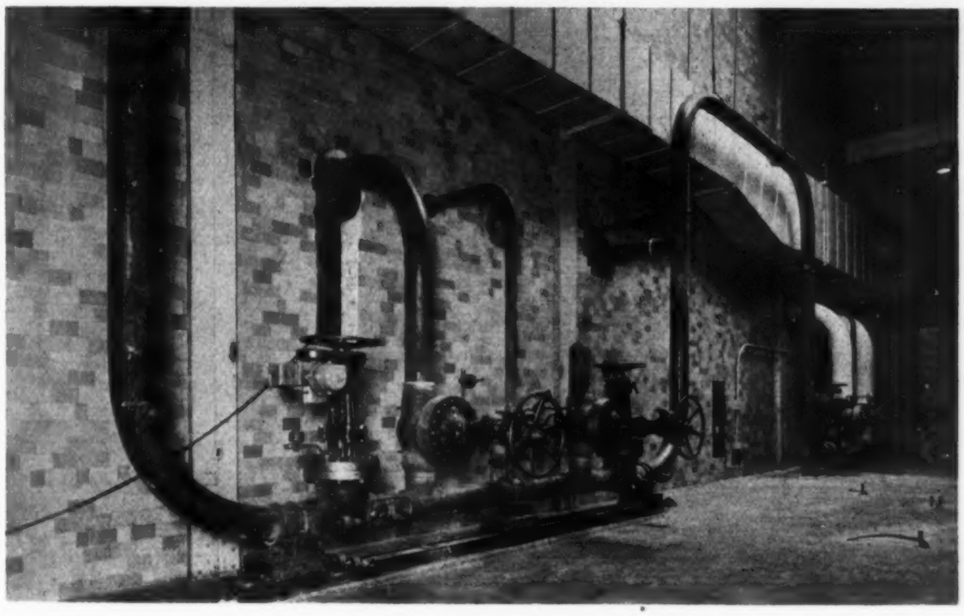
Since piping in general is too broad a topic to cover adequately in this discussion,[1] the subject will be approached from the angle of power-plant piping intended particularly for high-pressure or high-temperature service. Much that is said in this connection regarding the formulation of standards, specifications and codes could be extended almost equally well to embrace refinery piping where similar problems exist. Both the power and oil industries have cooperated closely with manufacturing interests on standardization groups for high-temperature piping. While the applications differ, much the same materials and dimensional standards are used by both industries.

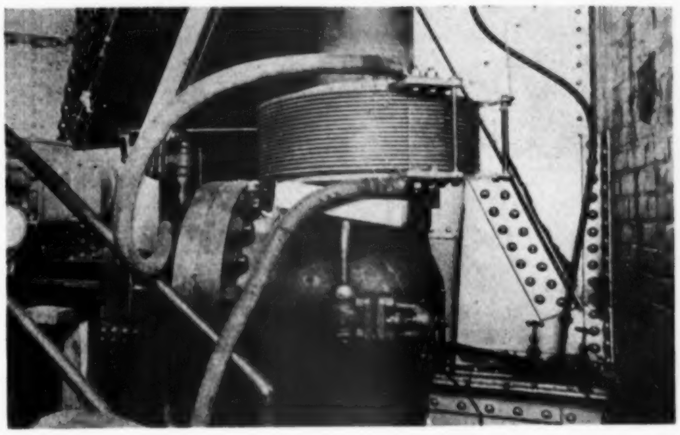
[1] Presented before the Boston Section, A.S.M.E., February 9, 1939.



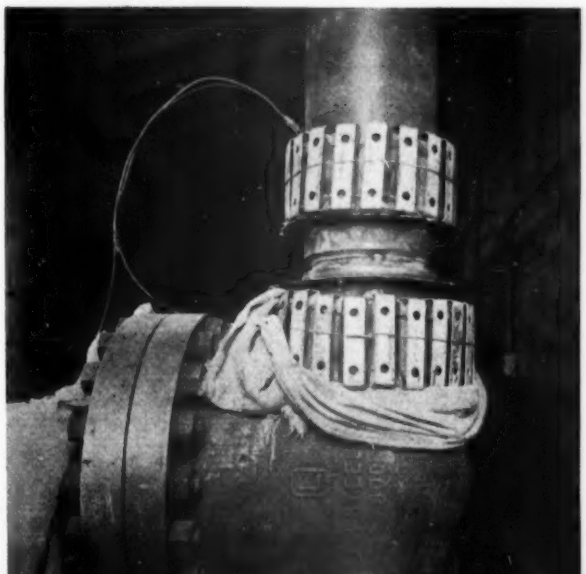
Comparison of boiler feed arrangements at plants of The Detroit Edison Company

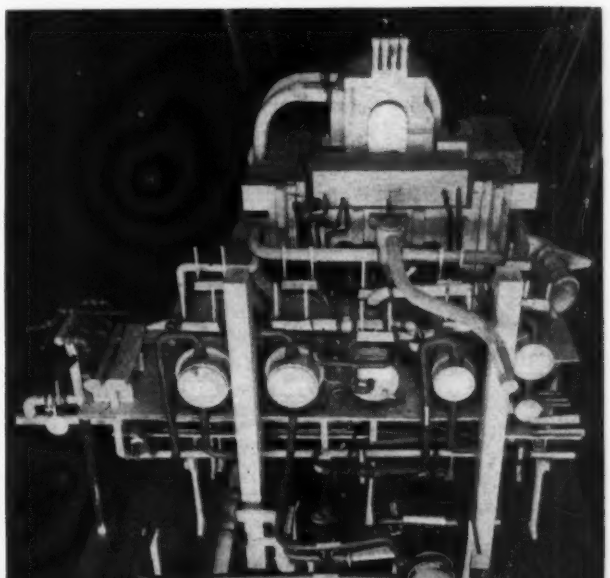
Main steam piping—10-in. welded header and manifolds at Delray Power House, No. 3





Left—Induction heating collar in place on pipe-to-valve weld
Lower, left—Electric-resistance preheater on 10-in. pipe-to-valve weld
Lower, right—Model of piping for 75,000-kw unit at Delray Power House, No. 3





Fifteen years ago about the only dimensional standards in existence for piping were those for the Briggs taper pipe thread; for standard weight, extra-strong and double-extra strong wrought pipe; for cast-iron water and gas pipe; and for standard-weight and extra-heavy cast-iron flanges and fittings. When steel flanges or fittings were wanted, the customary practice was to make them from one of the two or three series of cast-iron patterns already in existence. There were no independent lines of steel fittings or valves, nor were the steel fittings made to cast-iron dimensions suitable for steam pressures higher than 300 or 400 lb per sq in. Steel pipe normally was furnace-welded by the lap or butt methods rather than being made by the seamless process, as is so common today.

Misunderstandings frequently arose in purchasing material in those days through lack of piping standards and in their absence through failure to describe adequately the article wanted. For instance there were U.S. Standard bolts (whatever that meant) as distinguished from manufacturer's standard which, although suitable enough for some purposes, had undersized nuts which tended to chew into the $^1/_8$-in. oversize bolt holes of pipe flanges. Another source of confusion was the presence of two and three thicknesses of pipe for a single diameter in the so-called "standard weight" table. If the purchaser wanted the heaviest wall it was necessary for him to ask for "full weight," or else specify the actual thickness. Unless absolutely unavoidable, nothing was said about chemical composition, physical properties or manufacturing tolerances for either pipe or fittings, since responsibility for these mysterious criteria of quality was left almost wholly in the manufacturer's hands and the product sold on his reputation.

Present Requirements Exacting

As service conditions have become more severe, it has been necessary to establish more exacting requirements for dimensions and materials. People have come to realize that a nominal dimension is meaningless unless accompanied by plus or minus tolerances, and that a material is only as good as its chemical composition and physical properties. Workmanship is more carefully scrutinized and severe hydrostatic tests are applied to detect flaws or leaks. Minor defects are chipped out and repaired by welding instead of being smoothed over or peened tight. Castings and welds are sometimes explored by gamma rays or X-rays to locate hidden flaws, or pilot specimens are cut up to investigate the suitability of design. All in all, we are much more sure of the product than we were fifteen years ago.

Improved conditions have largely come about through a great deal of hard work and frank discussion between producing and consuming representatives working on committees organized to formulate standards and specifications. Some large concerns have representatives who devote all or part time to standardization activities, while numerous other companies participate to a lesser degree through sending engineers to occasional meetings. As a result, the piping field has been well covered with a comprehensive set of standards and specifications which embrace nearly all products concerned. Safety codes such as the A.S.M.E. Boiler Construction Code and the A.S.A. Code for Pressure Piping have been formulated to regulate the choice of materials and working stresses to suit service conditions and serve a useful purpose in linking standardization with actual practice.

Another phase of both manufacturing and purchasing operations which has come to be given more attention is the inspection of materials and workmanship. Careful attention to quality control, in order to insure getting a product which is up to expectations, is a necessary feature where working conditions are severe and failure in service cannot be tolerated. To insure independent action, plant inspectors usually report to the general manager direct or through some channel other than the plant production superintendent. This has helped materially in eliminating any tendency to avoid rejections as a face saver to the production department.

Purchasers' inspectors frequently inspect important orders at the manufacturer's plant where adequate facilities are available, rather than waiting for material to be delivered to the job. While some traveling expense is involved, this is offset in part by the saving in time in case of rejection with attendant waste in useless freight charges and possible delay in getting equipment into service.

Midwest Power Conference

Under the sponsorship of Armour Institute of Technology, with the cooperation of a number of universities and the local sections of several engineering societies, the Midwest Power Conference will be held this year at the Palmer House, Chicago, April 5 to 7. The program includes sessions devoted to research, small power plants, electric power generation, transmission and distribution, metals and welded construction, diesel power, rural electrification, problems in air pollution and power equipment. Following are some of the papers listed:

The Achievements of Research in Power, by L. W. Wallace
Developments in Central Station Power Plants, by Alex D. Bailey
Problems of the Small Industrial Power Plant, by F. Elwell
Small Utility, Municipal and University Power Plants, by G. A. Gaffert
Modern Developments in Power Cables, by Herman Halperin
Some Fundamentals of Generating Station Design, by G. G. Post
High-Pressure, High-Temperature Metallurgy, by J. C. Hodge
The Influence of Creep Studies upon Allowable Design Stresses, by J. J. Kanter
The Social Significance of the Development of Diesel Power, by L. H. Morrison
Diesel Tractor Power, by C. G. A. Rosen
A Survey of the Rural Service of the Wisconsin Utilities, by B. E. Miller
Contributions from the Rural Electrification Administration Program in Wisconsin, by V. M. Murray
Reliability of Power Supplies to Metropolitan Systems, by W. F. Sims
Reducing Pollution of Air by Power Plants, by R. V. Kleinschmidt
Chicago's Air Pollution Problem, by Loyd R. Stowe
Power Plant Auxiliaries, by G. C. Daniels
Railway Motive Power, by H. P. Allstrand
Power Plant Statistics, by Arthur L. Rice
American Pump and Turbine Development, by R. V. Terry

Several inspections are scheduled for Friday, and Thursday evening a joint dinner with the A.S.M.E. and A.I.E.E. will be held.

pH and pOH Explained

By P. B. PLACE

Combustion Engineering Company, Inc.

With the increasing application of pH to problems of feedwater treatment, corrosion, and high-pressure operation, there has developed a widespread acceptance of this symbol without, in many cases, a clear conception of what it means. This discussion attempts to explain what pH means, how the pH scale is derived, and the relation between pH and acidity and alkalinity, in such a manner that it may be understood by those who have had a minimum of chemical training.

LIKE the derivative and integral signs of calculus, the symbol pH conveys a sense of mystery to the uninitiated which tends to discourage understanding. It is an arbitrary symbol,[1] selected to express an arbitrary system of concentration units. It simply means concentration of hydrogen ions and the latter may be expressed also in parts per million, grains per gallon, percentage, or by any other acceptable means. It will be shown that the pH scale is merely a simple method of expressing concentrations that can only be expressed in clumsy and unwieldy numbers by the more common methods.

By technical definition, pH is the negative logarithm (to the base 10) of the concentration of hydrogen ions (when the latter is expressed in gram mol per liter at 22 C). The part in parenthesis is not usually given but is necessary to make the definition complete. The meaning of the various terms in this definition and the development of the pH scale will be explained in the following paragraphs.

Ions are simply electrically charged atoms or groups of atoms. Many substances when dissolved in water break up or dissociate into component parts which acquire a positive or negative charge during the process. This dissociation in solution is a dynamic process and an equilibrium is established between the amount of substance that is dissociated and the amount that is not dissociated. The dissociation is not necessarily complete and the degree depends on the substance, the amount in solution, the temperature and the presence of other substances. The concentration of the dissociated ions is the type of concentration with which pH is concerned but the ions involved are specifically those that produce acid and alkaline solutions, namely hydrogen ions and hydroxyl ions.

Hydrogen ions are positively charged hydrogen atoms and symbolized by H^+. Hydroxyl ions are negatively charged and are symbolized by OH^-. Acidity is a function of H ions and alkalinity is a function of OH ions. Pure water dissociates to a small degree into these ions according to the following equation:

$$H_2O \rightleftarrows H^+ + OH^-$$

and sets up an equilibrium between the liberated ions and the neutral undissociated water. As stated above, this equilibrium is dynamic, there being a continuous dissociation of the neutral water into ions accompanied by an equal association of ions into neutral water. Certain compounds when dissolved in water also dissociate to a variable degree and liberate free H or OH ions. A compound that liberates H ions is termed acid and one that liberates OH ions is termed alkaline or basic. Such compounds liberate either one or the other ion selectively so that solutions of acids or bases have an excess of H or OH ions, respectively. For example, hydrochloric acid and sodium hydroxide in solution partially dissociate as follows

$$HCl \rightleftarrows H^+ + Cl^-$$
$$NaOH \rightleftarrows OH^- + Na^+$$

The Cl and Na ions have no acid or alkaline effect but the H or OH ions associate with the similar ions already liberated in the water and form an excess of one or the other.

When there is an equal number of each ion present, the water or solution is neutral. When there are more H ions than OH ions the solution is acid and, conversely, when the OH ions predominate the solution is alkaline.

It has been found that for any given condition of acidity or alkalinity and temperature, only a fixed number of each of these two ions can exist under equilibrium conditions. It has been found further, that under all conditions, the product of the concentrations of H ions and OH ions is constant. This means that when either ion is increased by any process, the opposite ion automatically is reduced to maintain this constant product balance.

For example, if we assume that in a neutral solution we have 10 of each ion, the product constant for this assumed concentration is 100 and is fixed for other concentrations. If we increase the number of H ions by the addition of an acid (or the number of OH ions by the addition of a base) to 20, then the corresponding number of the opposite ion must decrease to 5 to keep the constant product of 100. Similarly, if the concentration of one ion is increased to 50, the concentration of the other must drop to 2. It will be noted that the sum of the ion concentrations varies with the condition, being 20 in the neutral state, and respectively 25 and 52 in the other cases. These assumed values have no significance and are used solely to illustrate the relationship.

By definition, pH values represent concentrations of

[1] A more indicative symbol might be C_H.

H ions expressed in gram mol per liter. A gram mol concentration is a molecular weight in grams dissolved in one liter (1000 grams) of water and is the common method of expressing chemical concentrations. Different atoms and molecules have different weights and the molecular weights represent the relative densities. It is, of course, impossible to weigh single atoms or to count the number of atoms in a gram, but from the relative or molecular weights, we know that whatever the number of ions in a gram of hydrogen ions, then the same number of OH ions will weigh 17 grams.

If, therefore, we have gram molecular weights of H or OH ions in a liter we have in the first case, 1 gram of H ions per liter and in the second case, 17 grams of OH ions per liter. In both cases, however, we have the same number of individual ions and this is the key to the conversion of pH concentrations to the more common weight concentrations such as parts per million. By definition, the pH scale is based on concentrations of the number of ions present whereas parts per million is based on the weight of the ions present.

A gram mol solution of hydrogen ions will contain 1 gram of ionized hydrogen per 1000 grams of solution, because the mol weight of hydrogen is 1. This is equal to 1 part by weight in 1000 or 1000 ppm. A gram mol solution of OH will contain 17 grams of ionized OH per 1000 grams of solution because the mol weight of OH is 17 and this is equal to 17 parts by weight per 1000 or 17,000 ppm.

It has been found that the fixed number of gram mols of H (and OH) ions in a neutral water or solution is 0.000,000,1 per 1000 grams of solution. Otherwise expressed, a liter (1000 grams) of neutral water will contain 0.000,000,1 gram mol of H ions weighing 0.000,000,1 gram, and also 0.000,000,1 gram mol of OH ions weighing 0.000,001,7 gram.

The concentration of H ions in neutral solution is therefore equal to 0.000,000,1 part in 1000 or 0.0001 ppm. Similarly the concentration of OH ions in neutral solution is equal to 0.000,001,7 part in 1000 or 0.001,7 ppm. These values are for room temperature conditions, or more specifically at 22 C, and apply to both pure water and to neutral solutions.

From these values, the per cent ionization in pure water may be calculated as follows, to give a better mental picture of the amount of dissociation:

Weight of H ions present	= 0.000,000,1 gram per 1000 grams of water
Weight of OH ions present	= 0.000,001,7 gram per 1000 grams of water
Weight of dissociated water	= 0.000,001,8 gram per 1000 grams of water
	= 0.000,000,18 gram per 100 grams of water
	= 0.000,000,18 per cent

The 0.000,000,18 gram of dissociated water per 100 grams of water is equal to 18 parts in 10,000,000,000 or 1 part in 555,555,555. Of this 1 part in 555,555,555, $^1/_{18}$ is hydrogen ion and $^{17}/_{18}$ is hydroxyl ion.

Since the product of the concentrations of these ions is a constant, it becomes $0.000,000,1 \times 0.000,000,1 = 0.000,000,000,000,01$ when the concentrations are expressed in gram mol per liter. When expressed in weight units, the constant becomes $0.000,000,1 \times 0.000,001,7 = 0.000,000,000,000,17$ if the weights are in gram per liter (parts per thousand) and this constant becomes 0.000,000,17 when the weights are in ppm.

From these constants, a table of concentrations of each ion can be built up as given in Table 1. In column 1 are given concentrations of the H ions expressed in gram mols per liter with the corresponding concentrations in ppm given in columns 5 and 6. Beginning at the neutral point with a concentration of 0.000,000,1 gram mol of H ions per liter, it is convenient to arrange the list of higher and lower concentrations in multiples of 10.

Inspection of column 1 will show that these values can be expressed in powers of 10. Thus the concentration of 0.000,000,1 gram mol per liter can be written 1/10,000,000 or $1/10^7$, or simply as 10^{-7}. The negative exponent of the last expression becomes the equivalent pH unit, namely 7. Similarly, the concentrations of 0.01 and 0.000,000,000,01 gram mol per liter may be written 10^{-2} and 10^{-11}, respectively, and the exponents 2 and 11 are the equivalent pH values for these concentrations. This development of the pH scale is given in columns 2, 3 and 4 in Table 1.

The use of logarithms and the base 10 is solely a matter of simplicity. Any other base could be used but the result would not be as simple numerically. It should be emphasized, as previously stated, that the pH scale is only a simplified and arbitrary method of expressing clumsy and unwieldy concentration values.

TABLE 1—CONCENTRATIONS OF H AND OH IONS REPRESENTED BY THE pH SCALE

Hydrogen ion Concentration Gm. mol/liter	Expressed in powers of 10	pH and pOH Scales		Concentrations in ppm H ions	OH ions
1.	10^0	0	14	1,000.	0.000,000,000,17
0.1	10^{-1}	1	13	100.	0.000,000,001,7
0.01	10^{-2}	2	12	10.	0.000,000,017
0.001	10^{-3}	3	11	1.	0.000,000,17
0.000,1	10^{-4}	4	10	0.1	0.000,001,7
0.000,01	10^{-5}	5	9	0.01	0.000,017
0.000,001	10^{-6}	6	8	0.001	0.000,17
0.000,000,1	10^{-7}	7	7	0.000,1	0.001,7
0.000,000,01	10^{-8}	8	6	0.000,01	0.017
0.000,000,001	10^{-9}	9	5	0.000,001	0.17
0.000,000,000,1	10^{-10}	10	4	0.000,000,1	1.7
0.000,000,000,01	10^{-11}	11	3	0.000,000,01	17.
0.000,000,000,001	10^{-12}	12	2	0.000,000,001	170.
0.000,000,000,000,1	10^{-13}	13	1	0.000,000,000,1	1,700.
0.000,000,000,000,01	10^{-14}	14	0	0.000,000,000,01	17,000.

pOH Scale

Acid and alkaline conditions can also be expressed by a pOH scale which is the same as the pH scale but in reverse numerical order. Such a scale is included in Table 1. The pOH value is the negative exponent to which 10 must be raised to give the concentration of OH ions when the latter is expressed in gram mol of OH per liter. A pH of 10 for example, represents the same concentrations of H and OH ions as a pOH of 4. In multiplication, logarithms are added so that the product constant for the pH scale becomes 7 + 7 = 14 and pH + pOH = 14.

In pure water the source of the H and OH ions is the water itself and obviously, for each H ion there will be a

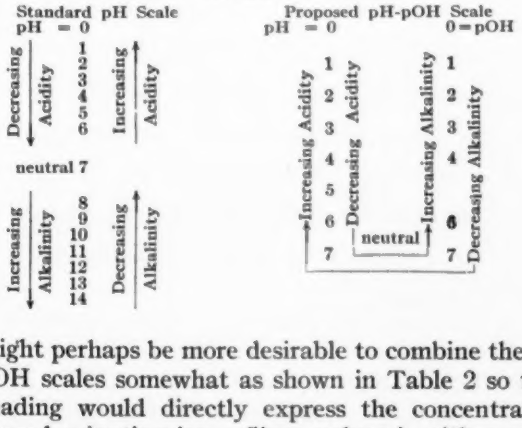
balancing OH ion. As mentioned above, in solutions, H or OH ions may be liberated selectively by acid or basic compounds dissolved in the water so that a predominance of either ion may result.

The addition of NaOH, for example, to water liberates extra OH ions without equivalent H ions to balance them. The result is somewhat like an election in which there are more OH voters than H voters. The result and influence of the election is alkaline in spite of a minority H vote. The greater the excess of OH votes, the weaker is the minority influence and the change is illustrated by the pH scale. Since the product of the concentrations of the two ions is constant, the addition of an excess of either ion upsets the H : OH balance and some of the minority ions have to leave the ionized state and become neutralized. In an acid or alkaline state, the minority ion is not eliminated but is simply reduced and a pH or pOH value represents definite concentrations of both ions.

It will be noted that the rate of change over the pH scale is logarithmic. That is, for each unit change in the pH value there is a ten-fold change in actual concentration, the rate of change increasing as the pH approaches either end of the scale. For example, a change in concentration from 1 ppm to 10 ppm of H ions reduces the pH value from 3 to 2, but to drop the pH value from 2 down to 1 requires an increase in H ion concentration from 10 ppm to 100 ppm. In operating boilers at a low pH, or in attempting to determine the pH value of condensate, it will be found that very small changes in concentration result in relatively large changes in the pH value. Conversely, when the pH of a boiler water, for example, is up around 12, wide changes in alkalinity have little effect on the pH value.

It is evident that expressions for the concentration of H ions are an indication of acidity because the latter is a function of these ions. It may not be so evident how alkalinity, which is a function of OH ions, can be indicated by expressions for concentrations of the H ion. This is possible because of the fixed relation between the number of each ion in the solution under equilibrium conditions. Instead of expressing the concentration of OH ions in an alkaline solution, the concentration of the minority H ion is given by the pH value and the alkalinity is thus expressed indirectly.

TABLE 2—pH AND pOH SCALES



It might perhaps be more desirable to combine the pH and pOH scales somewhat as shown in Table 2 so that any reading would directly express the concentration of the predominating ion. Since values in either scale, above 7, represent the minority ion, these values do not appear in such a table. Variations in acid condition are expressed by changes in pH and variations in alkaline condition by changes in pOH. At the neutral point, pH equals pOH.

The acidity or alkalinity of a solution, as commonly understood, is determined by a titration process and is a measure of the neutralizing capacity of the solution. These terms represent the total potential concentration of H or OH ions whether in the ionized state or not, whereas pH or pOH represents the intensity or availability of the ionized concentration. If all of the acidity or alkalinity of a solution were completely ionized into H and OH ions, the concentrations represented by the pH or pOH value would correspond to the concentrations represented by the titration results. In very dilute solutions, this condition is approximated but in most cases, the dissolved compounds are not completely ionized so that concentrations of ions represented by pH values and as given in Table 1, are usually much lower than the concentrations represented by titration results.

TABLE 3—PER CENT IONIZATION IN GRAM MOL SOLUTIONS

Sulfuric acid, H_2SO_4 to $2H^+ + SO_4^-$	= 51 per cent
Nitric acid, HNO_3 to $H^+ + NO_3^-$	= 82 per cent
Sodium hydroxide, NaOH to $OH^- + Na^+$	= 73 per cent
Ammonium hydroxide, NH_4OH to $OH^- + NH_4^+$	= 0.4 per cent

The degree to which compounds dissociate into ions when dissolved in water varies considerably. For example, in Table 3 is given the per cent ionization in gram mol solutions of two acids and two alkalies. In these solutions over eighty per cent of the nitric acid is present in ionic state but only four-tenths per cent of the ammonium hydroxide is ionized. Since pH represents the concentration of the ionized portions, such values may differ considerably from titration results which represent total acidity or alkalinity.

TABLE 4—CHANGES IN IONIZATION OF ACETIC ACID WITH DILUTION

Dilution	Per Cent Ionization
1	0.4
16	1.7
1500	14.7
15000	40.8

Dilution increases the per cent ionization and an example of this is given in Table 4 which shows the change in ionization of acetic acid with increase in dilution. There are also other factors that cause discrepancies between titrated concentrations and those represented by pH measurement but they need not be considered here. It is evident from the foregoing that the higher the concentration the greater the discrepancy because of the lower percentage of ionization. Since the rate of change in ion concentration increases rapidly at each end of the pH scale and the per cent of ionization decreases with increase in solution concentration, these two effects unite to accentuate the discrepancy. As pointed out, alkalinities can vary widely without much change in pH when the latter is up around 12.

To convert parts per million of H or OH ions to corresponding pH or pOH value, divide the ppm by 1000 to reduce the ppm to parts per 1000 (liter) and divide again by the mol weight of the ion involved. (H = 1 or OH = 17). Express the quotient as a decimal and the negative logarithms of this number to the base 10 are the corresponding pH or pOH values. To convert pOH to pH, subtract the pOH from 14 and the remainder is the

corresponding pH value.

EXAMPLE:

(a) 1.2 ppm H ion		(b) 374 ppm OH ion	
1.2/1000	= 0.0012	374/1000	= 0.374
0.0012/1	= 0.0012	0.374/17	= 0.022
Log_{10} 0.0012	= 7.079 − 10	Log_{10} 0.022	= 8.342 − 10
	= −2.92		= −1.66
pH	= 2.92	pOH	= 1.66
		pH	= 14.00 − 1.66 = 12.34

To convert pH or pOH values to corresponding ppm of H or OH ions, determine the corresponding pOH or pH value by subtracting the given pH or pOH value from 14. Determine the numbers of which the pH and pOH values are the logarithms to the base 10. Express the reciprocals of these numbers as decimals and multiply by 1000 and by the proper mol weight of the ion to give parts per million of the desired ion.

EXAMPLE:

(a) pH = 2.41 Corresponding pOH = 14.00 − 2.41 = 11.59

$10^{2.41}$ = 257
1/257 0.00389
0.00389 × 1000 × 1 = 3.89 ppm H ion
$10^{11.59}$ = 389,000,000,000
1/389,000,000,000 = 0.000,000,000,002,58
0.000,000,000,002,58 × 1000 × 17 = 0.000,000,043 ppm OH ion

(b) pOH = 2.41 Corresponding pH = 14.00 − 2.41 = 11.59

$10^{2.41}$ = 257
1/257 = 0.00389
0.00389 × 1000 × 17 = 66.1 ppm OH ion
$10^{11.59}$ = 389,000,000,000
1/389,000,000,000 = 0.000,000,000,002,58
0.000,000,000,002,58 × 1000 × 1 = 0.000,000,002,58 ppm H ion

It is hoped that the above discussion will serve to clarify some of the mystery of pH and to give a better mental picture of its meaning, derivation and relation to acidity and alkalinity.

Axial Balance in Multi-stage Centrifugal Pumps

By A. PETERSON

Ch. Engr. Pump & Compressor Dept.
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The author reviews briefly the several means that have been employed to counter-balance or eliminate hydraulic thrust in multi-stage pumps, particularly those operating under high pressure. He then describes and discusses in detail one method by which automatic balance is attained by means of disks and a leak-off opening around the shaft, without the use of a thrust bearing.

THE impeller of a single-suction centrifugal pump has an unbalanced hydraulic thrust directed axially toward the suction. It will be seen by reference to Fig. 1 that the area of the impeller web, lying within the circle of the wearing rings and outside that of the shaft, is acted upon from one side by pressure p_3 in the impeller chamber and from the other side by pressure p_1 in the suction. Outside this circle, both sides of the impeller are assumed to be acted upon by pressure p_3. Neglecting the comparatively small thrust caused by the water entering the impeller, the total unbalanced thrust acting upon the impeller becomes:

$$T = (p_3 - p_1)\left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right)$$

Due to rotation of water in the impeller chamber, pressure p_3 therein is slightly less than the discharge pressure, but, for the purpose of an example, it will be assumed to be the same as the discharge pressure and 200 lb per sq in. greater than the suction pressure. If the wearing-ring diameter D be taken as $7^1/_2$ in. and that of the shaft as 4 in.,

$$T = 200\left(\frac{\pi 7.5^2}{4} - \frac{\pi 4^2}{4}\right) = 6320 \text{ lb.}$$

For a six-stage pump operating at 1200 lb per sq in., the unbalanced thrust would be six times as much, or 37,920 lb. If the unbalanced pressure should be reduced by as much as 25 to 30 per cent because of rotation of water within the impeller chambers, this unbalanced thrust would still be large for a thrust bearing to carry. To take this load, even a Kingsbury thrust bearing, for example, would have a collar more than 12 in. in diameter, which is more than the diameter of the impellers of a 3500-rpm pump.

One of the earliest methods devised to balance or eliminate the thrust of multi-stage pumps having single-suction impellers was to provide wearing rings on the back, as well as on the inlet side of each impeller, with holes through the web or hub so that the pressure in the balancing chamber thus formed would be the same as that existing on the suction side of the impeller. This method has been abandoned almost entirely, as wear of the rings results in increased pressure in the balancing chamber, which sets up thrust. Furthermore, the efficiency is affected adversely by leakage between interstage bushings because of these bushings being subjected to a pressure difference corresponding to that developed by one stage. Also, the discharge stuffing box is subjected to full discharge pressure less than that developed by one stage, which, in most cases, necessitates a bleed-off arrangement with consequent loss in efficiency.

The following methods are now employed for counter-balancing, or eliminating, hydraulic thrust in multi-stage pumps:

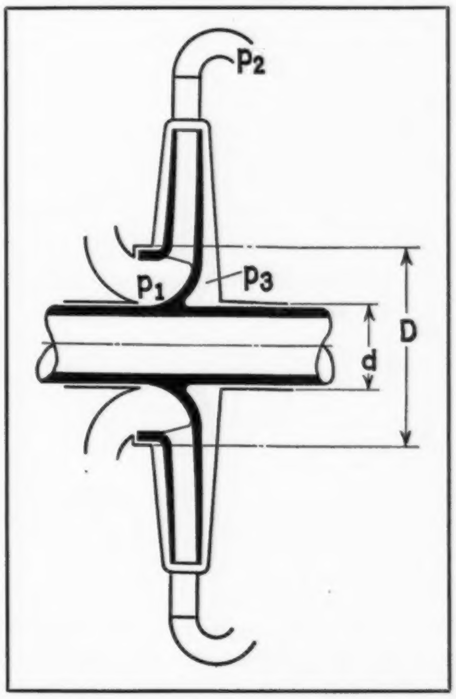


Fig. 1—Indicating unbalanced thrust on impeller

1. Double-Suction Impellers. If the same pressure exists on both sides of the impeller, a double-suction impeller obviously does not produce hydraulic thrust. In order to attain such a condition, the impellers must be located in the middle of the volutes and the castings must be symmetrical. As the great distance between impellers implies a long span between bearings, such double-suction multi-stage pumps are as a rule, limited to two or three stages, although pumps of this type have been built with as many as six stages.

2. Back-to-Back Single-Suction Impellers. This arrangement is extensively used and results in a hydraulically balanced pump, provided each impeller develops

the same pressure and the impellers are symmetrically located in the volutes. Under certain abnormal operating conditions, such as low inlet pressure or high suction lift, the first stage impeller may give a lower net pressure than do the remaining impellers, or under extreme conditions, practically no pressure at all. This obviously will result in thrust, the amount of which may be considerable, and thrust bearings of ample capacity must, therefore, be provided. An even number of stages is also necessary, unless the odd impeller is balanced individually by means of holes through the web.

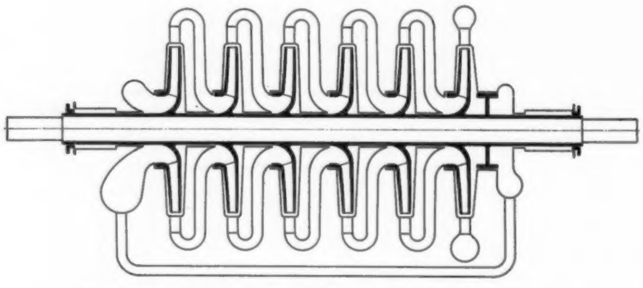


Fig. 2—Six-stage pump with balancing drum

3. Unbalanced Single-Suction Impellers All Facing in One Direction. This type of multi-stage pump, as shown diagrammatically by Figs. 2 and 3, is simple and rugged and is now very widely used for high-pressure boiler-feed service.

A six-stage pump with all impellers facing in one direction and designed for a pressure of 1200 lb per sq in. and a capacity of about 1000 gpm, may develop a thrust of more than 30,000 lb. One of the two principal methods used for counteracting this thrust, partially or completely, is shown diagrammatically in Fig. 2. A balancing drum at the back of the sixth-stage impeller sets off a balancing chamber in which suction pressure is maintained. If the balancing drum were of the same diameter as the impeller tightening ring, or $7^1/_2$ in., as in the given example, the thrust in the direction of the suction from the six impellers would be $6 \times 6320 = 37{,}920$ lb, and the balancing drum would give a thrust in the opposite direction of $(6 \times 200)\left(\frac{\pi 7.5^2}{4} - \frac{\pi 4^2}{4}\right) = 37{,}920$ lb, so that the pump would, theoretically, be in perfect hydraulic balance. However, since the thrust of the six impellers is, for reasons previously mentioned, not as great as calculated, there will be a resultant thrust toward the discharge of the pump, the amount of which it is impossible to calculate exactly, as is, also, the diameter of the balancing drum to balance the pump completely, so that it is still necessary to provide a thrust bearing.

The second method of counteracting the thrust is indicated in Fig. 3. This was adopted in 1913 by the company with which the writer is now associated. In this arrangement the balancing area is larger than the circle enclosed by the wearing rings on the suction side of the impellers, so that while the pressure in the balancing chamber is lower than the pressure generated by the pump, it is not as low as the suction pressure. Furthermore, this pressure is automatically controlled by axial movement of the rotor to maintain an exact balance at all times, so that no auxiliary thrust bearing is necessary. Balance is not affected by wear of the balancing device. It has been used successfully ever since and for pressures as high as 1600 lb per sq in.

The effect of enlarged diameter of the balancing chamber may be explained by reference to Fig. 4, wherein the diameter D_1 of the balancing drum is greater than the tightening ring diameter D. The thrust developed by the balancing drum is directed toward the discharge end of the pump and opposes the unbalanced thrust of the impellers. Neglecting, as before, the reaction and reduction in pressure on the sides of the impeller due to rotation, and leaving out of consideration the balanced pressures on impellers outside of diameter D_1, it is seen that the thrust on the balancing drum is

$$T = \left(\frac{\pi D_1^2}{4} - \frac{\pi d^2}{4}\right)(p_d - p_x).$$

This thrust must be equal to the thrust developed in the opposite direction by the six impellers if the rotor is to be in hydraulic balance.

Using the figures previously assumed and, in addition, selecting $8^1/_2$ in. for the diameter D_1 of the balancing drum, the pressure p_x required to balance the six-stage pump designed for 1200 lb pressure with zero pressure on the suction may be calculated. The thrust developed by the six impellers is 37,920 lb. Further:

p_d = 1200 lb per sq in.
d = 4 in. and

$$37{,}920 = \left(\frac{\pi 8.5^2}{4} - \frac{\pi 4^2}{4}\right)(1200 - p_x)$$

from which $p_x = 341$ lb per sq in. That is, when the pump is operating at 1200 lb, a pressure of 341 lb in the balancing chamber theoretically gives perfect hydraulic balance. If the pump were operating at a head lower than 1200 lb, a lower pressure would be required in the balancing chamber, and vice versa, but regardless of operating conditions, the balancing chamber pressure will always be higher than the suction pressure.

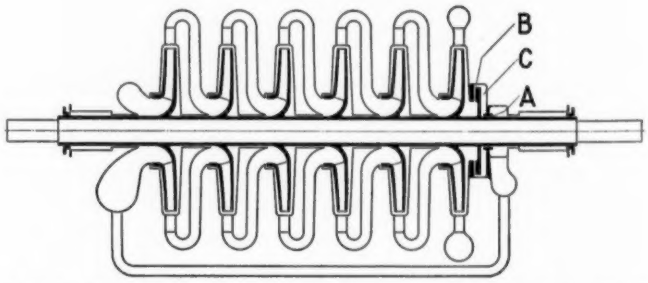


Fig. 3—Six-stage pump with balancing disks and leak-off arrangement

Obviously, it is impossible in practice to regulate the balancing pressure by hand control, but automatic control is obtained by a simple arrangement. Referring again to Fig. 3, the balancing rings are made in the form of disks and the leak-off water is throttled into the suction of the pump through a fixed opening, A, around the shaft. The rotor will then shift axially to hold a pressure in the balancing chamber such that balance is obtained under any normal or abnormal operating condition, even when the impellers are not spaced symmetrically in the casing or if different heads are developed by the several impellers.

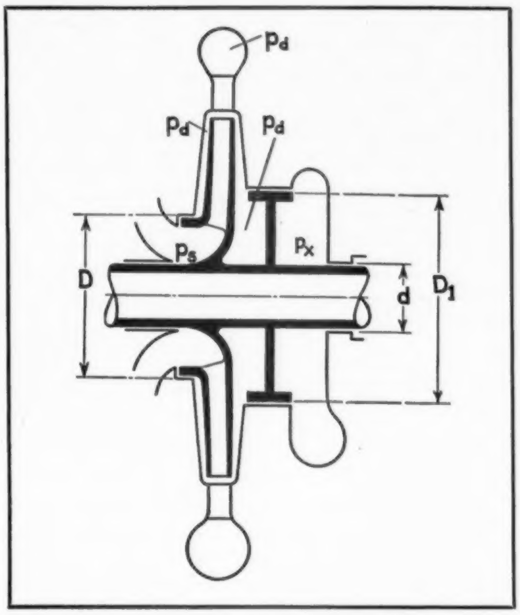


Fig. 4—Showing effect of large diameter balancing chamber

Operation of this automatic hydraulic balancing arrangement is as follows: Water passes from the discharge of the last stage impeller between the faces *B* of the revolving and stationary balancing disks into the balancing chamber *C*, whence it returns to the suction through the annular opening *A* around the shaft. Thus, if the two balancing disks are in contact, preventing leakage between their faces *B*, suction pressure will exist in the balancing chamber *C*. However, in that case, because of the discharge pressure of 1200 lb per sq in. acting upon the balancing disk, there would be a resultant thrust toward the discharge end of the pump and, as the rotor is free to move axially, the balancing disk faces would move apart until the leakage into the balancing chamber became sufficient to build up a pressure of 341 lb per sq in.

Going to the opposite extreme, if the clearance area between the balancing disks is much greater than the area of the annular opening *A* around the shaft, a pressure approximately equal to the discharge pressure will exist in the balancing chamber, which naturally will result in thrust toward the suction of the pump, so that no matter what the operating conditions are a pressure will automatically be established in the balancing chamber that will balance out all thrust.

Wear of the balancing disks does not affect the automatic balancing action, nor does it decrease the efficiency of the pump. Assuming that the faces of the two balancing disks have worn a total of $^1/_{32}$ in., all that happens is that the rotor shifts $^1/_{32}$ in. toward the suction, the pressure in the balancing chamber remaining the same except for possibly a small change due to the impellers being slightly off center; but the rotor remains in hydraulic balance. So long as no wear occurs in the annular opening *A*, there will be no increase in leakage and no loss in efficiency, as the pressure drop across the bleed-off will remain the same, or practically so. The balancing disks are so proportioned that the pressure drop through the bleed-off is relatively small, consequently there is little wear at this point.

Since in the disk-balanced pump there is no unbalanced thrust to be taken up, no thrust bearing is required so long as the pump is supplied with liquid. The location of the rotor is definitely so fixed that rubbing cannot occur between the balancing disks, and hundreds of disk-balanced pumps without thrust bearings are in satisfactory operation, some after more than twenty years of continuous service. However, if the pump be started dry, or should lose its suction, there is a possibility that, without a protecting bearing, the balancing disks might come into contact, as from thrust transmitted through the coupling from the driving unit. To eliminate any possibility of rubbing under such abnormal conditions, a spring-loaded protecting bearing, as shown at *K*, Fig. 5, is provided to hold the faces of the balancing disks about $^1/_{32}$ in. apart until liquid is being pumped and sufficient pressure is developed in the balancing chamber to overcome the spring tension.

As supplied in connection with the automatic hydraulic balancing arrangement, the protecting bearing is either of the Kingsbury thrust type or of the ball type, depending upon the speed and size of the pump. When the pump is not running, or is running without water, the spring presses the housing of the protecting bearing against a fixed shoulder in the bearing bracket, holding the balancing disk faces about $^1/_{32}$ in. apart. The force exerted by the spring need be no more than is required to move the pump rotor in an axial direction. The spring-loaded protecting bearing does not interfere with the functioning of the hydraulic balancing arrangement, as the load transmitted to the shaft by the spring through the bearing simply results in a slight increase in pressure in the balancing chamber.

Failure of the protecting bearing, from lack of oil or any other cause, does not impair the operation of the pump. The damaged parts can be removed and, if no spare parts are on hand, the pump, if supplied with liquid, can be started and will operate indefinitely without the protecting bearing.

The question has been raised as to what would happen if the last stage, or stages, of a disk-balanced pump were vapor-bound and the first ones not. No failure has occurred from this cause, which fact may be explained as follows:

Assume that the first three stages are developing a pressure of 600 lb and that the remaining three stages

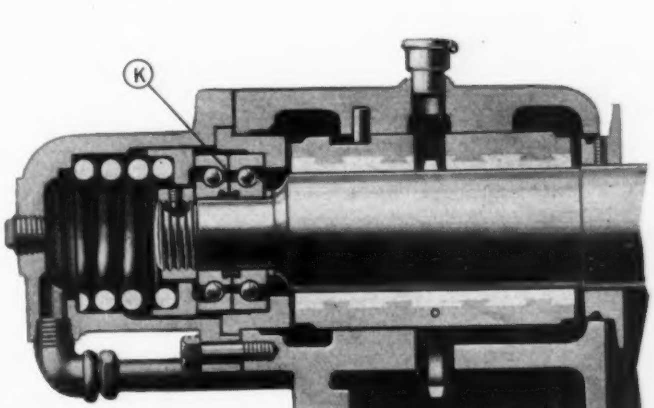


Fig. 5—Showing spring-loaded protecting bearing

become vapor or air bound, which would mean that no pressure is developed by the last three impellers. Although the corresponding part of the pump would be under 600 lb pressure without any water in it, the balancing arrangement would still function properly and the disks could not come into metallic contact with each other. Using in the formula

$$T = \left(\frac{\pi D^2}{4} + \frac{\pi d^2}{4}\right)(P_d - P_x),$$

a thrust of 18,960 lb and a P_d of 600 gives a P_x of 170.5 lb. The only difference between such abnormal operation and normal conditions is that vapor or air would then pass between the balancing disks instead of water.

Multi-stage pumps fitted with this automatic balancing arrangement have fed boilers in high-pressure steam plants successfully for years. One such pump has been in operation for over seven years, handling water at 210 F against discharge pressures of from 1600 to 1700 lb per sq in., and with a suction pressure of 325 lb. The pump has been in actual operation nearly 50,000 hr, which would be equivalent to almost ten years' service in a power plant where two pumps are operated alternately for equal intervals. The original balancing disks and bleed-off bushings are still in use and have not worn sufficiently to affect the efficiency to a measurable extent, which is quite remarkable in view of the high water velocities set up by around 1300 lb pressure drop through the balancing device.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

The Engineers' Manual Second Edition

By Ralph G. Hudson

This contains a compilation of engineering formulas, mathematical expressions and constants, such as the practicing engineer or student frequently needs, but which are often scattered among numerous books of reference. They are arranged systematically and each is preceded by a statement in which its application, the symbology of the involved physical quantities and definite units of measurement are indicated. Included are algebraic expressions, trigonometric functions, areas and volumes of geometric figures, analytical geometry, calculus, differential equations, relations of mass and space, kinetics, beams and bars (including tables), orifices and other hydraulic applications, heat and combustion formulas, draft and numerous electrical relations. There are also appended tables of logarithms, squares, cubes and roots, condensed steam tables and conversion factors.

For the practicing engineer the aim has been to present the information in such a way that results may be obtained quickly and accurately, even in a branch of engineering to which he may have given little attention. In preparing the second edition the author has revised and extended many of the tables of physical constants, the new steam table values have been incorporated and many additions have been made.

Bound in a flexible cover and of convenient dimensions, 5 × 8 in., this book of 340 pages sells for $2.75.

Steam-Engine Principles and Practice

By Terrell Croft

Revised by E. J. Tangerman

The first edition of this book made its appearance in 1922 and had a wide circulation. Much of the material was basic and has not been altered by subsequent developments in the field. This has been retained as well as descriptive matter and practical information concerning engines of that period, many of which are still in operation. However, in the interim designs have been improved and advances have been made in practice, which rendered desirable a revision of the text to include present practice. Much new material has been added including classified data supplied by various engine builders. The contents include functions and principles of the steam engine, indicators, various types of valves and their settings, governors, simple and compound engines, condensing and non-condensing operation, later types of engines, engine testing and efficiencies, lubrication, selection, operation and repair of steam engines. Numerous problems are included.

The treatment is essentially practical and the book is commended to operating engineers. It will be found most useful in preparing for operating license examinations. There are over 500 pages, 5 × 8 in., including 547 illustrations. The price is $3.50.

Design of Industrial Exhaust Systems

By John L. Alden

The purpose of this book is to tell the engineer how to design and build or how to specify an exhaust system for dust and fume removal. The text includes, flow of fluids, hood forms, air flow through hoods, pipe resistance, piping design, dust separators, low-pressure conveyors, centrifugal exhaust fans, structural details and system planning, field measurements and their interpretation. The aim of the author has been to dispel most of the mystery and misunderstanding surrounding exhaust work and to express many of the trade conventions in straightforward engineering terms.

The book contains 220 pages, 5 $^1/_2$ × 8 $^1/_2$ in., fully illustrated and including numerous tables and curves. The price is $3.

Creep Data

This volume compiled by the joint A. S. M. E.-A. S. T. M. Research Committee on the Effect of Temperature on the Properties of Metals contains 864 pages covering data on high-temperature creep characteristics of metals and alloys. There are charts of stress and corresponding creep rates for each type of material at different temperatures; curves of temperature versus creep rate (0.10 per cent per 1000 hr) for each material wherever sufficient data were available; tabulated forms giving detailed descriptions of each material, such as its form, heat treatment, chemistry, hardness, grain size, physical properties, including impact values, and photomicrographs showing the initial microstructure and the microstructure of the completed creep specimens.

The price of this volume is $12 in the United States and Canada, and $14 elsewhere.

Standards for Compressed Air Machinery

The American Standards Association announces the completion and approval of the first safety code for compressed air machinery and equipment, under the sponsorship of the American Society of Mechanical Engineers and the American Society of Safety Engineers. The Code, which has been developed out of the combined experience of manufacturers, users, insurance companies and governmental groups, is published in a nine-page booklet and includes specific recommendations for the construction and use of compressors, tanks, pipe lines, etc. The price is 30 cents.

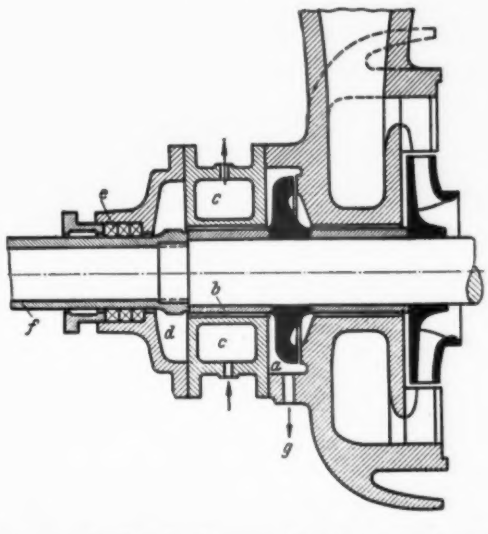
STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Stuffing Boxes for Centrifugal Pumps

An article by Dr. F. Krisan in *Zeitschrift des Vereines deutscher Ingenieure* of November 26, 1938, discusses and illustrates different types of pump stuffing box arrangements for handling water at high pressures and high temperatures.

The principal difficulties with centrifugal boiler feed pumps and also circulating pumps for forced-circulation boilers, which must operate at temperatures at least as high as that corresponding to the steam pressure, have been encountered in the stuffing boxes. It is desirable to avoid packing against hot water under high pressures and the designs of stuffing boxes discussed are such that the hot water is kept from coming in contact with the packing. This is accomplished by providing a cooling path along the shaft between the pump chamber proper and the stuffing box through which the leakage water must pass on its way to the packing. The cooling path is formed by a water-cooled chamber which surrounds the shaft by a close clearance and through which chamber relatively cold water is forced. If the leakage is sufficiently slow, the leakage water will be suitably cooled in its flow through the cooling path to the packing. A soft packing material is usually used, which must be sufficiently elastic and must not change its shape under high unit pressures. The shaft should run true and be free from vibration in its bearing. Such a cooling path may also be used in combination with sealing water.



High-pressure boiler feed pump having a cooling path for the leakage water to the stuffing box
a hydraulic unloading chamber; *b* cooling path; *c* cooling-water chamber; *d* chamber in advance of stuffing box; *e* stuffing box; *f* shaft sleeve; and *g* relief water, carried back to the suction or to the suction well

For single-stage pumps it is preferable to have an overhung wheel so as to avoid two stuffing boxes. In the case of multi-stage feed pumps the combination of an economizer pump and feed pump may lend itself to limiting the hot water to a single stuffing box. In multi-stage feed pumps the pressures on both stuffing boxes may be made substantially alike, and equal to the suction pressure, by providing an hydraulic unloading device for the axial thrust which simultaneously serves as an unloading means for the pressure on the stuffing box on that side of the pump.

Large Turbines in Japan

Commenting on the recent completion of a second 75,000-kw three-cylinder turbine-generator by a Japanese firm for a new power plant at Amagasaki, Osaka, *Engineering and Boiler House Review* (London) of February observes that this plant is to have four such units operating at 600 lb per sq in. steam pressure and 860 F. The rotative speed is 1800 rpm and the high-, intermediate- and low-pressure cylinders have, respectively, 13, 10 and 10 stages. The final stage-heating temperature is 356 F. The shaft of the high-pressure element is of nickel-chromium-molybdenum steel and those of the intermediate- and low-pressure elements are of forged carbon steel as provided in the Japanese engineering standards. Nickel-chromium-molybdenum steel is employed for the high-pressure disks. The low-pressure machine is of the divided-exhaust type and is provided with two vertical condensers.

An earlier plant of the same company, the Kansai Joint Steam Power Company of Osaka, contains six 50,000-kw turbine-generators. Thus the combined capacity of the two stations will be 600,000 kw.

Test of Boiler at Barton Power Station

Tests on a 200,000-lb per hr Simon-Carves boiler at the Barton Power Station, Manchester, Eng., are reported in *Engineering* of February 3. The extension to this station was placed in service last May and consists of two boilers which supply steam to a 50,000-kw turbine-generator. These units are of the three-drum bent-tube type and employ two circulatory systems—one from the steam drum, through external downcomers to distribution headers in the lower part of the circuit, thence upward through the water walls; the other circuit being up the front bank of tubes to the front steam drum, through the crossover tubes to the rear bank and down to the bottom drum. Firing is with chain-grate stokers.

The steam conditions at the time of test were 363-lb gage at the stop valve and 862 F. Slack of 11,500 Btu per lb heating value, and having a proximate analysis of 9.3 per cent moisture, 34.2 per cent volatile, 50.3 per cent

fixed carbon and 15.5 per cent ash was burned, with an average fuel bed thickness of $6^1/_4$ in. The fuel burning rate was 47.5 lb per sq ft of grate; 8.21 lb of water were evaporated per pound of coal as fired, or 10.01 lb equivalent evaporation from and at 212 F. The air per pound of fuel was 10.16 lb at a temperature of 343 F at the stoker windbox. Feedwater was delivered to the economizer at 301 F, and the temperature of the gases leaving the air heater was 240 F. Combustible in the ash was 4.6 per cent; CO_2 at the boiler outlet 14.9 per cent, and at the air heater outlet 12.46 per cent.

Under these conditions an overall efficiency for the unit of 86.25 per cent was obtained, including power for the auxiliaries which amounted to 2.2 per cent.

New Australian Power Station

The Steam Engineer (London) of February describes the East Perth "B" Station in western Australia which was formally dedicated on January 20. This new boiler plant which is tied in with the older and adjacent low-pressure Station "A" supplies the City of Perth. It contains three 135,000-lb per hr bent-tube boilers of International Combustion design supplying steam at 600 lb, 800 F to a 25,000-kw condensing turbine-generator which has been located in the turbine room of Station "A."

Collie coal of relatively low heating value, 8769 Btu average, and high moisture content is burned in pulverized form. This coal, despite its poor quality, costs the equivalent of $5.35 per ton and it was therefore essential to design the plant for high thermal efficiency, including the installation of heat-recovery equipment.

Each boiler is served by two mills and the coal is fired into completely water-cooled, fin-tube furnaces by Lopulco burners of the turbulent type. The furnaces are of the dry-bottom type. Steel-tube economizers with shrunk-on cast-iron fins and plate-type air heaters are provided. Two motor-driven and one steam-driven boiler feed pumps, each of 300,000 lb per hr capacity, supply the three boilers. To take care of expansion in the pipe lines, corrugated pipe and bends are employed with flexible hangers.

Cottrell electrostatic precipitators are installed on the roof to handle the fly ash. This, together with the soot from the hoppers and the ash from the combustion chambers, is delivered into concrete troughs and sluiced to a pit from which the mixture of ash and water is pumped to a concrete bunker and the water drawn off.

Conserving Steel

Under the German "Four-Year Economic Plan" much attention is being given to the conservation of steel in all types of construction. A recent article in *Zeitschrift des Vereines deutscher Ingenieure* shows how this has been applied to power plant buildings by employing lattice-frame construction for the boiler house and wherever possible in other parts of the plant, except the steelwork carrying the crane and that supporting the bunkers. Welding has been extensively applied and headroom is relatively low. The total weight of the building steelwork is approximately 0.68 lb per cu ft.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Air and Erosion Eliminator

Condenser Service & Engineering Company has issued a bulletin describing its "Air and Erosion Eliminator" designed to prevent oxygen attack on the inlet ends of condenser tubes and electrolytic or galvanic action resulting in dezincification and pitting of the tubes. This device, which has been on the market for several years, consists of perforated screen plates in front of the tube sheet on the inlet end of the first pass which breaks up and agitates the water and liberates the entrained air. Half-venturi nozzles, between the plates and the tube sheet, are piped to a manifold leading to the circulating water discharge pipe from the condenser and remove this air. Electrolysis is diverted to the plates rather than to the tube sheets.

Ash Conveyors

United Conveyor Corporation has just brought out a 24-page catalog containing information on its "Hydroveyor," a pneumatic conveyor used primarily for handling fly ash, soot, dust and coal siftings in large industrial plants and central stations. It is fully illustrated with installation photographs and views of component parts which are described. Diagrams of typical layouts are included.

Automatic Controllers

An attractive and colorful new catalog, with ring binding, describing in detail pump governors, regulators, liquid level controllers, valves, traps and strainers manufactured by the Fisher Governor Company, is just off the press. This new catalog is divided into 12 sections and contains 16 pages of capacity charts useful in sizing controllers properly for all fluids and all conditions. There are described and illustrated 183 different automatic controls and steam specialties and numerous installation photographs and diagrams are included. Dimensions, working pressures and prices are given in detail.

Boilers

A new 40-page catalog describing bent-tube boilers as designed and built by Combustion Engineering Company, Inc., has just come off the press. Two-, three- and four-drum types are covered together with numerous setting arrangements. Included are various special designs of units for capacities ranging from 100,000 to 1,000,000 lb of steam per hour. Particular attention is given to features of the three-drum design. Twenty-five different setting drawings are included, as well as many photographic illustrations showing furnaces, boiler details, construction views and manufacturing operations. Space is also devoted to the C.-E. steam washer as applied to bent-tube boilers.

Boiler Water Level Control

An illustrated catalog has been issued by McDonnell & Miller describing a line of boiler water-level controls for application to low-pressure boilers (up to 150 lb) of various capacities. Included also are low water cut-offs and pressure-limit controls. These are described in detail and applications illustrated.

Compressors

Sullivan Machinery Company has prepared a new catalog describing its line of air and gas compressors built in sizes from 378 to 1600 cu ft per min displacement (60 to 250 hp) for commercial pressures. This 16-page catalog illustrates a variety of the many industrial installations made since this compressor was announced in 1937 and shows the feature construction in detail.

Condensate Purity Instruments

A new 20-page illustrated catalog on "Micromax" condensate-purity instruments for the steam plant has been brought out by Leeds & Northrup Company. It shows how a knowledge of condensate conditions helps to effect important operating economies and describes a reliable electrical method for continuously determining variations in condensate purity. It also describes Micromax recorders which automatically draw a chart record of condensate conditions, and, if contamination occurs, actuate an alarm to warn the operator, or in addition, operate a motorized valve to divert impure condensate to waste. Illustrations are included showing typical applications.

Expansion Joints

Expansion joints of the stainless steel bellows type for pressures of 50, 150, 300 and 600 lb in standard sizes of 2 in. to 36 in. and temperatures up to 750 F, in standard designs, or 1000 F in special designs, are covered in a bulletin issued by Foster Wheeler Corporation. These joints are applicable to power station piping, loop-system heating plants, oil refineries and process plants. Various forms of this type of joint are illustrated.

Gear Drives

Double helical gears are generally recognized as essential parts of marine turbine propelling units and are also widely applied in small and medium size turbo-generator works systems, drives of high-speed blowers and compressors from standard speed motors, diesel-engine drives of slow-speed machinery, etc. While the majority of such gears have met all expectations as to quiet operation, reliability and long life, there have been certain instances in which short life, noise, pitting and faulty operation have resulted from the use of incorrect methods in figuring tooth pressures. Much interest, therefore, attaches to the simplified analysis of the gear rating problem given in a paper by A. Peterson of the De Laval Steam Turbine Company, which is reprinted for distribution.

A new booklet explaining the uses, adaptations and developments of all types of geared drives has just been announced by the Westinghouse Electric & Mfg. Company. Included are single-, double- and triple-reduction gearmotors; single- and double-reduction speed reducers; special vertical and right-angle vertical geared drives; single- and double-reduction heavy duty mill units; horizontal speed-reducers with shafts in vertical plane; and geared drives for special problems and conditions.

Pumps

Rotary displacement pumps for handling fuel and crude oils, lubricating oils and hydraulic oil, are described in Catalog L-31, issued by the De Laval Steam Turbine Company. This pump has only three moving parts, a power rotor and two sealing rotors, which carry helical teeth that mate as they roll to form fluid-tight enclosures traveling continuously from suction to discharge, resulting in steady delivery without pulsation. There are no reciprocating parts, valves, timing gears or separate bearings, and only one stuffing box, which is under suction pressure. The pumps can be directly coupled to steam turbines or electric motors and are adapted to all capacities and pressures.

Properties of Nickel

Bulletin T-15 issued by The International Nickel Company contains extensive tabulated data on the mechanical properties and physical constants of nickel. The section on mechanical properties deals chiefly with the correlation of tensile properties with hardness, and with the more specialized mechanical properties, such as ductility, strength at elevated temperatures, endurance limits, torsional and shear strengths, compressive strength, toughness, rigidity and hardness. The section on the corrosion-resisting properties of nickel is a brief summary of its behavior under a very wide variety of exposure conditions. Working instructions are included giving summaries of the proper procedures for hot and cold working, annealing, machining, welding and brazing and pickling.

The bulletin contains a separate section devoted to the more commonly used special nickel alloys such as low-carbon nickel, "D" Nickel and "Z" Nickel.

Steam Turbines

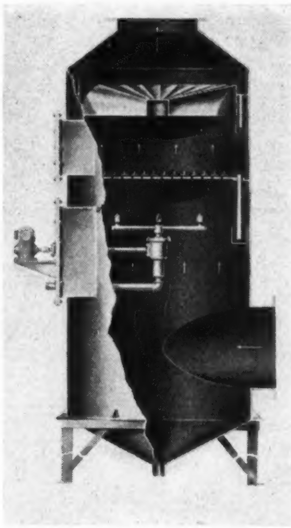
A turbine, in the 100 to 2000-hp range, manufactured for every type of industry using mechanical and electrical power, is described in a new booklet issued by the Westinghouse Electric & Mfg. Company.

The design is flexible enough, through selection of proper number of stages, governor and control, to give maximum efficiency and reliability. The turbines run at 1000 to 5500 rpm, and are for steam pressures up to 650 lb, steam temperatures to 750 F, exhaust pressures to 200 lb, vacuum to 29 in. mercury and extraction pressures to 200 lb.

NEW EQUIPMENT

Air and Gas Scrubber

The Peabody Engineering Corporation, announces a new scrubber for removal of fog, dust and other particles from gas and air. In this model, known as the "Triple-Action Scrubber," the separation of impurities is by a three-step process.



Gas enters tangentially near the base of the scrubber and is there relieved of coarse particles by cyclonic action. The gas passes upward through a zone of water or scrubbing liquid, supplied by slowly rotating sprays, operating at 10 to 15 lb pressure. Dust particles mingle with water droplets at this stage. Continuing its travel, the gas encounters a plate with coarse perforations. On passing through these, the gas velocity is greatly increased and with it the velocity of the dust and water droplets. The mixture of gas, dust and droplets is shot through the plate perforations directly at square impingement baffles, constantly wet, and arranged so that the stream coming through each plate perforation strikes its individual baffle at maximum velocity. The dust particles and water droplets, on impact with the wetted baffle merge with the water surrounding the baffle.

A liquid overflow pipe, located slightly above the level of the baffles, carries off the dust-laden water, which leaves at the bottom of the scrubber shell. The gas or air, freed from impurities, is deflected around the baffles and continues upward toward the outlet of the shell. Eliminator vanes, located below the outlet, entrap any droplets of water carried upward in the gas stream, thus delivering dry gas.

Air-Flow Meter

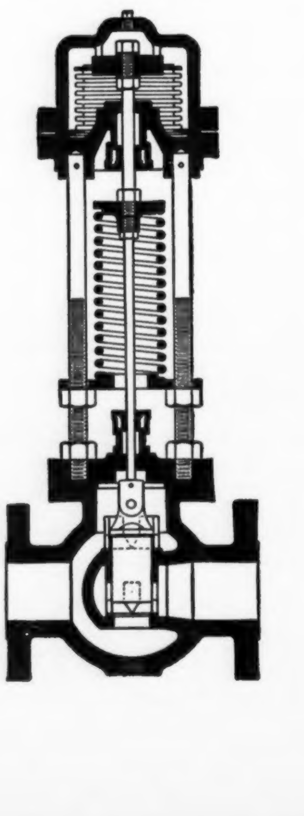
Bailey Meter Company has developed a diaphragm-operated air-flow mechanism for its standard steam flow–air flow boiler meter. Use of this mechanism simplifies the application of boiler meters to steam generating units in which high static draft conditions are likely to be encountered. With it, air-flow connections may be made at locations in economizers, air heaters, or boilers where high draft conditions preclude the use of the usual oil-sealed air-flow mechanism.

The mechanism which fits into the standard Bailey boiler meter employs a large diaphragm clamped between the flanges of a metal housing. Air-flow connections from the boiler are made to this housing on each side of the diaphragm so that changes in differential pressure are measured and recorded in terms of air flow. The diaphragm is of silk, coated with a compound to render it air tight and impervious to heat and moisture.

Air supplied to the boiler for combustion is recorded by this mechanism and is coordinated on the boiler meter chart with the record of steam flow. When these records coincide on the 12-in. uniformly graduated chart, ideal combustion conditions exist and the boiler operator can see that no adjustments to fuel or air supplies need be made. If the rate of steam flow exceeds the air flow, a deficiency of air is recorded and to restore economical combustion conditions, the operator need only increase the air supply until the pens again coincide.

Pump Governor

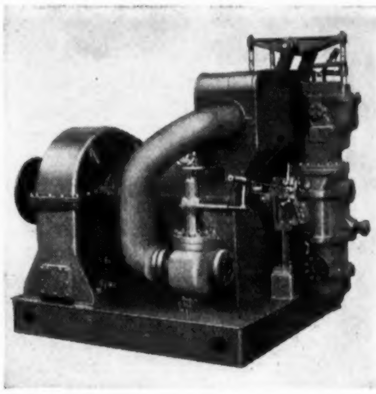
Northern Equipment Company has brought out a new pump governor, the Copes Type SL, designed especially for service on steam-driven reciprocating pumps or on centrifugal pumps driven by small steam turbines. It is suited for excess pressure service in boiler feeding where the maximum excess pressure is no more than 75 lb per sq in. It may also be used for constant-pressure service where the controlled pressure is not to exceed 75 lb. It is furnished in sizes from $^3/_4$- to 3-in., in the 250- and 300-lb pressure standards only.



The actuating element, a 4-ply brass sylphon bellows, is protected against water hammer or sudden changes in pressure by a stabilizer, and the governor is spring-loaded. A balanced bevel-seating valve piston gives added assurance of instantaneous response to pressure variations, so that control is accurate under all loads.

Steam Turbines

Improved multi-stage steam turbines for general purpose drives are announced by Westinghouse Electric & Manufacturing Company. These turbines range from



100 to 2000 hp, 100 to 5500 rpm and are particularly suitable for driving pumps, fans, compressors, pulverizers and process machinery.

Modifications of one basic design provide for condensing, condensing extraction, non-condensing, non-condensing extraction or mixed pressure service. The steam turbines known as Type "M" can be supplied for steam pressures up to 650 lb, steam temperatures to 750 F, exhaust pressures to 200 lb, vacuum to 29 in. of mercury, and extraction pressures to 200 lb.

Test Outfit for Measuring Dissolved Oxygen

The chemistry of the dissolved oxygen test is relatively simple. A solution of manganese salt and a solution containing a strong alkali and an iodide are introduced into the water to be tested. The two solutions interact to produce a precipitate of manganese hydroxide, which is rapidly oxidized by, and in proportion to, any dissolved gaseous oxygen present. The solution is then made acid, whereupon the oxidized manganese compound reacts with the iodide which was added with the alkali and liberates free iodine equivalent to the oxygen originally present. Un-

til the latter action is completed, the sample must be carefully protected from the oxygen of the air. A starch solution is then introduced, to which the free iodine gives a blue color. The liberated iodine is then measured by adding, drop by drop, a standard solution of sodium thiosulfate until the blue color disappears. The volume of sodium thiosulfate used indicates the amount of dissolved oxygen that is contained in the original sample of water.

The standard Winkler procedure outlined above has been adapted by Bull & Roberts, consulting chemists in New York City, to meet the needs of the practical engineer, by designing a testing cabinet which embodies simplicity without sacrifice of essential accuracy. The cabinet is of welded steel construction, with baked enamel finish, and all apparatus clips are of stainless steel. The reagent pipettes (liquid transfer tubes) are equipped with bulbs which automatically measure the desired quantity of the test solution, no pipettes into which the reagent is sucked up by the mouth being used. An automatic self-leveling burette (measuring tube) is used in the final titration (drop-by-drop measurement). To gather the sample of water to be tested, sampling bottles which minimize the danger of trapping air at the completion of the sampling operation are provided. The bottles have Neoprene stoppers to avoid the negative interference which arises from the use of vulcanized rubber stoppers. The cabinet measures 17 × 13 × $7^1/_2$ in., and all apparatus is firmly secured against breakage.

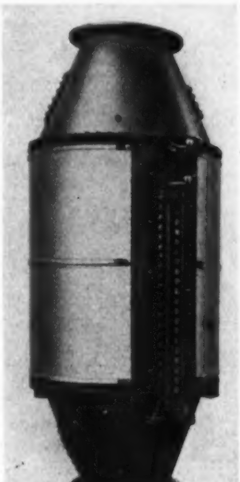
Valve Positioner

The Bristol Company, announces the development of a new valve positioner for use on diaphragm control valves to overcome the effect of friction in the valve stem and top. This pneumatic device is recommended for use on air-operated control installations where close control is of paramount importance and particularly on those where there is considerable process lag. It assures a proportionate valve stem travel for the slightest change in the pressure of the air from the controller. Any friction that might tend to

prevent the valve disk from coming to its intended position in order to maintain close control is overcome.

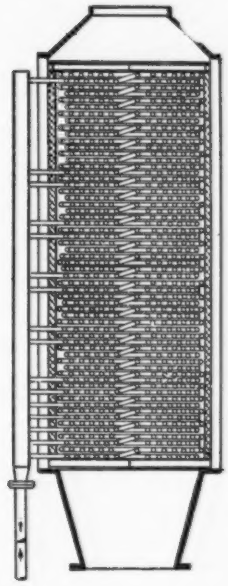
Waste-Heat Steam Generator

Combustion Engineering Company, Inc., is now offering forced-circulation waste-heat boilers for both stationary and ma-



rine applications, the designs being based on lately acquired La Mont patents for forced-circulation boilers.

In this type of unit the pump supplies seven to eight times, by weight, as much water to each tube as is converted into steam, and the coils of small tubing are arranged in parallel between an inlet and an outlet header. A nozzle at the entrance to each tube insures adequacy of flow in the parallel circuits. In the waste heat unit shown herewith for utilizing the heat in diesel engine exhaust, the tubes are spirally coiled, but the arrangement of heating surface and the location of the drum are flexible and can be adapted to any space conditions. Where an auxiliary



boiler already exists it may be used as a receiver for the La Mont system and thus eliminate the necessity of a separate drum, The design involves a minimum number of joints.

While such applications to diesel engines usually employ exhaust gas temperatures of 500 to 800 F with steam generated at 50 to 180 lb per sq in., the boiler is also applicable to very much higher gas temperatures and steam pressures in stationary waste-heat installations. Of the 700 La Mont steam generating units now in service abroad, a representative number are of the waste-heat type.

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